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MAINTENANCE FACTORS IN BUILDING DESIGN

ROZITA BINTI ARIS

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

May 2006

I declare that this thesis entitled “Maintenance Factors In Building Design” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

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Date : **18th May 2006**

Dedicated to my beloved husband Mohamad Rosli Haron, my children and parent, for their everlasting support and encouragement to complete the course of studies.

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ABSTRACT

The degree to which the design of a building embraces maintenance considerations has a major impact on its performance. In Malaysia for instance, most designers claimed to have knowledge and experience on building maintenance aspects but only few are aware of the importance to consider maintenance factors during design stage. A survey was carried out on 38 designer firms (architectural, civil & structural consultant firms) and 30 maintenance firms located in Shah Alam and Kuala Lumpur districts. The aim was to find out the building defects and other maintenance problems that are heavily attributed to design deficiencies, inadequate information gathering, material limitations and lack of maintenance knowledge. The data were analyzed using SPSS (Statistical Package of Social Sciences). Findings show that main problems that the maintenance firms are currently facing are caused by building design deficiencies, poor construction quality and poor performance of building which is directly related to functional layout, choice of building material and choice of building equipment. It appears that designer firms consider maintenance factors like ease of cleaning, access to cleaning area and repair and replacement to be the least important when designing buildings. Lack of communication between designer firms and maintenance firms as well as building users or owners resulted in designer firms not fully aware of the maintenance-related problems frequently reported by building owners. Designers seem to be neglecting the benefits of designing for ease of maintenance that can prolong the building lifespan, reduce defects rate and therefore reduce maintenance costs. Therefore, it is important for project team management to develop awareness and policy from the very early start of project to ensure the concept for ease of maintenance can be understood and implemented successfully in local construction practice.

ABSTRAK

Rekabentuk bangunan yang mengambilkira aspek penyelenggaraan sewaktu fasa rekabentuk, mempengaruhi prestasi bangunan tersebut apabila ia beroperasi sepenuhnya. Di Malaysia contohnya, kebanyakan perekabentuk bangunan (yakni khususnya para arkitek dan jurutera rekabentuk) mendakwa mereka mempunyai pengalaman mencukupi dalam bidang penyelenggaraan tetapi masih ramai yang kurang mengambilkira aspek penyelenggaraan sewaktu sesebuah bangunan direkabentuk. Satu kajian tempatan telah dijalankan ke atas 38 buah syarikat rekabentuk (konsultansi arkitek dan/atau kejuruteraan awam/struktur) dan 30 buah syarikat penyelenggaraan bangunan di sekitar Shah Alam dan Kuala Lumpur. Tujuan kajian dijalankan adalah untuk mengenalpasti masalah-masalah penyelenggaraan bangunan masakini, khususnya masalah yang berpunca dari kegagalan rekabentuk, kekurangan maklumat, penggunaan bahan binaan yang tidak menepati fungsi bangunan dan kurangnya pengetahuan berkenaan aspek penyelenggaraan. Data yang diperolehi dianalisia menggunakan SPSS (Statistical Package of Social Sciences). Hasil kajian menunjukkan, masalah-masalah utama yang selalu dihadapi oleh syarikat penyelenggaraan bangunan masakini berpunca dari tiga sumber; kegagalan rekabentuk bangunan dari segi contohnya fungsi bangunan, pembinaan kurang berkualiti yang antaranya puncanya adalah kelemahan penyeliaan dan kegagalan atau kelemahan fungsi bangunan itu sendiri sewaktu dalam fasa pembinaan. Kurangnya interaksi antara pihak rekabentuk dan pihak penyelenggaraan mengakibatkan perekabentuk kurang peka dengan permasalahan yang dihadapi oleh syarikat penyelenggaraan dan pengguna bangunan di peringkat operasi. Oleh yang demikian, adalah penting bagi pengurusan sesebuah projek menitikberatkan isu-isu penyelenggaraan sedari awal lagi bagi mengurangi masalah tersebut di atas.

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CHAPTER 1

1.1 Introduction

With the increasing costs of new construction, the effective maintenance of the existing building stock has become even more important. Increasingly, building owners are beginning to accept that it is not in their best interest to carry out maintenance in a purely reactive manner, but that it should be planned and managed as efficiently as any other corporate activity. Inevitably, this has placed new demands on building owners, requiring them to adopt a more systematic approach to their work. This is where the concept of design for ease of maintenance comes in.

Modern buildings are designed to meet higher builder standards which demand longer life span and control of the decaying processes. This demand high maintenance budget. Therefore, it is of great importance to consider maintenance of building aspects during design stage for the future performance of the building. Somehow, with the help of modern technology, new inventions in building equipments and design software, building design becomes easier. With little input, all work will be computed by computer software.

This research reviews on the issues of design maintenance factors in civil and architectural design aspects and proposes eight critical factors for designers to take into

account during design stage. A design maybe executed perfectly well within the Code of Practice that have been enforced onto, but the building may fail to perform properly if these parameters are imperfectly set and/or neglected.

1.2 Problem Statement

Reports and researches have shown that some countries, especially developed nations like Singapore and United States, have already practice total building performance audit, benchmarking and quality management procedures in guiding developments towards improved maintainability (Chew *et al*., 2004). Malaysia despite, being a developing country, are moving up quickly in every area, including building construction. We can be proud with our large and complex projects which are equipped with modern, latest technology in terms of aesthetic values, performances, energy saving and services offered. However, modern buildings are designed to meet higher building standards than in previous time, and this demand more long lasting durable building conditions. The influence of design on the maintenance of buildings is greater than ever before (Arditi *et al*., 1999).

The costs of design and construction are minor compared to the total costs of a structure. Typically, 50% to 80% of the total cost will occur during (the) in-service life and the earlier design, development, construction and manufacturing activities maybe as little as 25% of what will subsequently be needed to operate, maintain and overhaul the new asset (Griffin, 1993). A large amount of the country's maintenance resources is being expended on corrective or remedial measures to buildings and their services due to design or construction defects. Therefore, by reducing the number of design defects, the amount of maintenance expenditure can be reduced (Assaf *et al*., 1996).

Design firms often claim themselves quite knowledgeable in maintenance issues, using the statement that their personnel is exposed to training in these matters at one time or another. In addition to that, property managers and maintenance consultants are consulted in designing some projects, mostly in the schematic and preliminary design phases only. Somehow, reliance on the design's staff to occasional maintenance training is not sufficient to design a building with longer life cycle without incorporating the factors that contribute a higher level of ease for future maintenance works. Without proper rules and guidelines that need to be followed during design stage, the objective of extending the life span building with low maintenance budget cannot be achieved (Arditi *et al*., 1999).

A critical individual that should be consulted at all stages especially during the early design is a maintenance manager or consultant. These individuals provide insight to the effects of changes made to the systems and particularly how the systems will interface. If the system is unfamiliar to the designers as well as to the building owner's regular maintenance staff, then it is critical for the design team to consult the system manufacturer to provide information relevant to the education and training required for the proper operation and maintenance of the systems being considered.

Therefore, this research was conducted and hope to become a useful reference for local architects and design engineers to incorporate crucial maintenance factors during design phase to ensure a successful implementation of design for maintenance concept, particularly for future projects in Malaysia.

1.3 Aim and Objectives

The aim of this study is to enhance the quality of designs produced by the local architects and engineers through incorporation of design for ease of maintenance concept at the design stage. In achieving this aim, two objectives have been outlined. They are:

(i) To identify building defects that are related to poor maintenance consideration during design stage

(ii) To identify critical maintenance factors in civil and architectural designs

1.4 Brief Methodology

The first step of the study was identifying research problem which covered the significance, objective and scope of study followed by exploratory research of the literature. Information was gathered through two sources. Firstly through journals, books and reports and secondly through preliminary interviews which took place through telephone conversation.

Questionnaire for maintenance and designer practitioners were later developed using the information obtained from potential respondents and were handed over to respondents by hand, facsimile, email and by mail. After three weeks, the researcher received back the questionnaires either through post or collected by hand whereby hand-collection gave the researcher the opportunity to conduct interview sessions with the respondents.

The data were then compiled, analyzed and discussed with the assistance of frequency and analysis index and from there, the researcher concluded the findings together with recommendations to improve the problem.

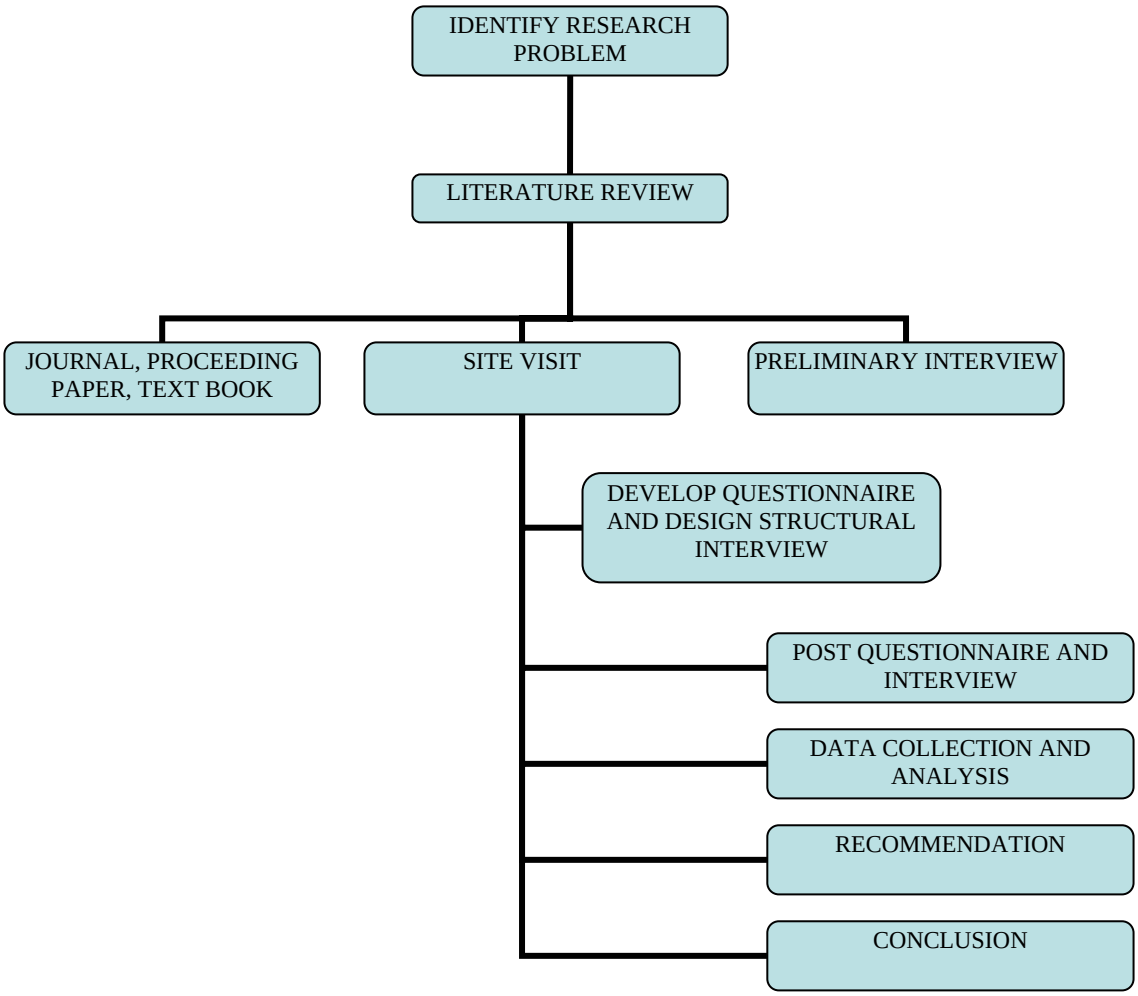


Figure 1.1 Methodology flowchart

1.5 Scope of Work

This research was focused on building construction, mainly on building deficiencies due to poor design practices as well as to come up with factors for a better understanding and hence assist them to come up with a good design which incorporate maintenance factors. Information and data were collected from local library and journals.

Structured interviews was conducted on building design firms within the Shah Alam and Kuala Lumpur districts. Interviews was carried out using questionnaires. Questionnaires had been distributed randomly to approximately 100 respondents which include consultancies (Architectural, Civil & Structural) and maintenance organizations/contractors within Shah Alam and Kuala Lumpur districts. The target is to

(i) find out the design firms' existing level of maintenance-related knowledge
(ii) identify the factors they consider when designing building
(iii) determine the most critical factors to design with consideration of the ease of maintenance concept.

CHAPTER 2

MAINTENANCE

2.1 Introduction

The definition in BS3811 : 1964 indicates that there are two processes in building maintenance, they are :

(i) retaining – refers to preventive maintenance works carried out in anticipation of failure and
(ii) restoring – refers to corrective works carried out after failure.

There is also the concept of acceptable standard. Acceptable standards vary as no absolute standard is acceptable to everyone and acceptable standards do change with time. There are various definitions for maintenance :

(i) *A combination of any actions carried out to retain an item in , or restore it to, an acceptable condition* (BS3811 : 1964)

The definition above suggests a positive activity, which is controlled and therefore planned so as to achieve a defined end result (White, 1969). The definition also suggests that there is a range of acceptability with upper and lower limits between which the condition of the multi-complex must be maintained.

(ii) White's definition is as follows :

Maintenance is synonymous with controlling the condition of a building so as that its pattern lies within specified regions.

This definition recognizes that, subject to a minimum set by the statutory authorities, there is no single standard of condition, which will be equally applicable to all the different types of building and circumstance likely to be met in practice. This flexibility is suited to an industry whose products are so varied and long lived as those of the construction industry (Edward, 1980).

In summary, the main trust of maintenance lies in managing the technical component of a building. However, of equal importance is the need to consider methods of planning and organizing the work and to adopt appropriate accounting procedures to ensure that maximum return is achieved from investments made to preserve the building asset (Lim *et al.*, 1991). Moreover, keeping buildings in a good state of repair reflects the quality of life and prevents anti-social aspects of maintenance (De Jonge, 1990).

2.2 Maintenance Policy

The objective of maintenance policy may be simply stated as keeping buildings in appropriate condition by the most economic means. For instance, what is the most appropriate condition and how best it may be achieved is the substance of maintenance policy. The principal factors influencing maintenance policy are outlined in the following paragraphs.

BS3811 defines maintenance policy as a strategy within which decisions on maintenance are taken. It can be defined as the ground rules for the allocation of resources between the alternative types of maintenance action that are available to management. They are effectively decisions made on the allocation of human, material and monetary resources (Reginald Lee, 1983). Therefore, to achieve a locative efficiency, there is a need to consider issues relating to : What maintenance has to achieve? What is to be gained? How shall we proceed?

2.2.1 What Maintenance Has To Achieve?

This should be viewed in accordance to the organization's overall multi-complex needs. It requires the combination of management skills, financial resources and engineering knowledge applied to physical assets in pursuit of economic life-cycle costs. It is essentially the setting up of the organization objectives for building maintenance. The objectives may be to satisfy insurer requirement, to provide a safe, secure and efficient working environment and to avoid deterioration of physical asset.

2.2.2 What Is To Be Gained?

The benefits can be short term or long term and can be reflected in the areas of physical, financial or human resources. Maintenance will preserve the physical characteristics of a building and its services. This mean fewer breakdowns and lower future maintenance costs, higher productivity, less wastage of materials and improve organization sales revenue. The improved condition of the building gives positive effect to the users resulting in lower staff turnover, better customer relation and public image.

2.2.3 How Shall We Proceed?

The first step is to lay down operational and cost objectives with the identification of maintenance tasks, the standard to be achieved and limits of costs. This will lead to proper balance between preventive and corrective maintenance, priority to be accorded to different type of work, work distribution between in-house staff and contractors.

2.3 Maintenance Planning

Maintenance planning should start at the design stage of any building project and should continue throughout the life of that building. In this the building owner and or user, must play an active part.

This lack of continuity is unfortunate, for much relevant information for future reference can be obtained if a proper feedback system can be devised. The problem is that many buildings are destroyed not by outside forces such as weathering factors like heavy rains or drought but by insufficient/improper design during the design stage, through bad housekeeping, inadequate maintenance and neglect during its full operation. Two cases for example. The first concern with the thousands of crack appearances on 31 out of 33 piers in MRR2 highway bridge. As reported by the professional consultant company from United Kingdom who conducted a post mortem, the cause is insufficient design. The second concern with a recent school inspection which produced complaints of water penetration through a wall, resulting in damaged decoration. A quick investigation and the removal of two tennis balls, soft drink cans and a large quantity of leaves from a gutter cured the problem instantly. Typical of the sort of minor problem which can grow into a major one through neglect, and which can be multiplied in many buildings.

All new buildings , as a matter of course, should be provided with a maintenance manual, so that a building owner can look after and maintain his building in use just as he does his car (Mills, 1980). The design of building maintenance manual requires many skills and close cooperation between the design team, the client and the maintenance team. The larger the building, the more important early considerations of these matters become. Unless the owner’s objectives and requirements are clearly stated and understood, the effectiveness of the design team will be reduced and it will be difficult for them to specify to the client the limitations he must expect within the budget limits imposed. A lack of clarity at this stage can be a source of dissatisfaction on the building owner and occupiers’ side and argument between them and the design team for years after the building is handed over (Mills, 1978).

2.4 Building Maintenance

Building maintenance is a major activity in most countries. Building maintenance is subjects, which have attracted growing interest in recent years. Maintenance however, have always been inextricably associated with buildings, from the earliest times when men sheltered from the elements in primitive wattle-and-daub huts up to the present day, when civilized man can erect skyscrapers and glass palaces using modern building materials such as concrete, steel, glass and synthetics. Man has always been confronted with the question of upkeep (Bos, 1999).

The function of building maintenance is to maximize the aesthetic and economic values of a building as well as increase the health and safety of the occupants. Some of the specific maintenance objectives are as follows (Magee, 1988) :

(i) Perform daily housekeeping and cleaning to maintain a properly presentable facility

(ii) Develop and execute a system of regularly scheduled maintenance actions to prevent premature failure of the facility and its systems and components

(iii) Complete major repairs based on lowest life-cycle cost

(iv) Identify design and complete improvement projects to reduce and minimize total operating and maintenance costs

(v) Operate the facility utilities in the most economical manner while providing necessary reliability

(vi) Provide for easy and complete reporting and identification of necessary repair and maintenance work

(vii) Monitor the progress of all maintenance work

(viii) Perform accurate cost estimating to ensure lowest cost solutions to maintenance problems

(ix) Maintain a proper level of material and spare parts to support timely repairs

(x) Accurately track the costs of all maintenance work

(xi) Schedule all planned work in advance, and allocate and anticipate staff requirements to meet planned and unplanned events

(xii) Maintain complete historical data concerning the facility in general and equipment and components in particular.

(xiii) Continually seek workable engineering solutions to maintenance problems

For maintenance and building repair system to be efficient and effective, a comprehensive policy needs to be formulated which will enable the organization to optimally allocate its limited resource. One of the most essential aspects, which should be incorporated in the policy, is the objective of the maintenance system. Besides preserving the building so that it can effectively serves its function, other significant aspects in the maintenance objective, which should not be neglected, is the emphasizing on customer focus (Azhari Abd Rashid, 1997).

2.5 Building Owner and Maintenance

The primary initiators of maintenance are the owner and/or user, although other interested parties, e.g members of public, may exert either a direct or an indirect influence on the amount of work undertaken. The role of building owners with respect to maintenance considerations during design will vary depending on their interest in the use of the building. Their primary aim is to preserve the value of asset so as to ensure a long-term trouble-free investment capable of providing a continuous and satisfactory return. The objective is to achieve this with minimum expenditure (Lee, 1987). Clearly,

the maintenance policy must be related and according to the fundamental aims and objectives of the individual or organization that owns or occupies the building; in a commercial context, is dependant on making a profit (Mills, 1980). Building owners must get involved in the role of knowing how to recognize problems and determining the most effective ways to deal with them with the help from designers and maintenance consultants.

There is a growing awareness worldwide of the importance of the maintenance of constructed facilities (Bourke and Davies, 1997; Cash, 1997,1999; Horner et al. 1997; Cane et al.1998; Van-Winden and Dekker, 1998; Underwood and Alshawi, 1999). Maintenance experts and modern building owners especially in developed countries like United State, France and Singapore have become acutely aware that the conventional in-house maintenance practices are too fragmented to cope with the high-technology building services. Their in-house staff also lacks the resources, skills and knowledge to meet the rising expectations of the users and to provide the quality service required for this new generation of intelligent building (Soh Chee Keong, 1997). This is due to the growing complexity of buildings, the increasing proportion of systems in them and the higher level of service. That is why, Singapore for instance, has taken steps to enhance the maintainability of buildings. Singapore's Ministry of National Development has set up The Construction 21 Steering Committee (CTC) in 1999 to monitor and focus on the enhancement of maintenance program in order to help attain greater productivity and other breakthroughs. The committee strongly agree that in order to achieve greater efficiency for the constructed building, it is indisputable for every party, including the owner to monitor closely all project stages in totality (CTC, 1999).

However, different view and perspective are applied in Malaysia. Especially in times of bad economics, maintenance budgets are very much subjected to reduction. Even in good times, there is usually a reluctance to spend in order to preserve the

condition of the assets due to the fact that building owners place great emphasis on keeping the capital costs within budget. Maintenance standards are usually met at the barest minimum rather than aiming for the optimum standards. Also, building maintenance is often overlooked as a business function. It often plays as second fiddle to the other business operations. Therefore, far less advance management tools are adopted by owners to effectively manage the buildings.

The researcher believe that the neglect of building maintenance in Malaysia is serious that intervention at national level must be done. Since maintenance problems in building facilities are heavily attributed to many factors, whereby the most important ones are design limitations and construction knowledge, owners must be made aware that insufficient funding of design and construction will impact future maintenance capabilities. Owners will continually be challenged to meet greater demand for improved maintenance standard with less staff, less capital and in less time than ever before if nothing is to be done (Chong, 1996).

Therefore, in order to create the sense of national responsibility for building maintenance, education in the importance to preserve and taking care of existing assets is vital and will be appreciated and worthwhile as creating new assets. Government can help establish a specific rehabilitation fund which will allow owners with modesty funds to get access to the money for repairs on reasonable terms. Coupled with this is the possibility of statutory regulations which require regular building inspection reports in order to determine how much maintenance is required to ensure building perseverance (Miles and Syagga, 1987). At the same time, designers must be able to demonstrate to building owners that increases in design and construction costs due to designing for ease of maintenance can be offset by reduced future maintenance costs.

CHAPTER 3

BUILDING DEFECTS

3.1 Introduction

Defects within new buildings are areas of non-compliance with the Building Code of Practice and published acceptable tolerances and standards. Older buildings, or buildings out of warranty period, may not comply with these standards but must be judged against the standard at the time of construction or refurbishment. Obvious examples of a defect are cracked, damaged or deteriorated brick walls, leaking showers, dampness to a building as well as, excessive sagging to a roof or ceiling. To determine the actual defect requires a professional inspection to find the cause of the problem and to provide the right information for remedial works. Also, defects may exist in areas not accessed by a homeowner such as rooftops. Roof construction can also be affected by fire damage and must be assessed as structurally adequate.

A defect within a building may be a result of sub-standard work or lack of expertise at time of construction. Examples are concrete cancer (spalling) and are a result of poor building practices during the 1960's and 1970's, but was amended with a

new Concrete Code in the 1980's. An example of non-compliance is roof construction to buildings older than 1930 where the framework does not comply with current standards. The framework is adequate for the original roof loads, but may be inadequate if the roof is changed. The changing of the roofing can create a building defect.

A defect in an older building may also be caused by lack of adequate maintenance. General maintenance items, such as rebedding and repointing of roof hip and ridge tiles, repainting, normal wear and tear as well as ageing are not a defect. Typical cracks to brickwork and contours of timber floors affected by clay soil movement is not structural and therefore not a defect.

A building, product or application can become defective through age and lack of maintenance and professional advice should be obtained to ensure that replacement or works undertaken are using materials and current systems of application that are appropriate to the building. Examples of building defects are where structural settlement cracks are occurring to brickwork, non-compliance with termite systems, excessive structural sagging to a roof, ill-fitting windows and doors, leaking showers and sagging ceilings.

A professional inspection and report will not only provide accurate information on defects, as well as maintenance items that require attention so that remedial works are undertaken to a suitable standard. Defective or inadequate termite systems can allow termites to access a building and cause substantial damage including structural damage to timbers.

3.2 Building Defects

Problems in buildings can be broadly categorized as defects or deterioration. Defects arise due to errors or omission or negligence by the designers or contractors. Deterioration on the other hand, is the natural process which is unavoidable , although maybe minimized by exercising care in design, material selection and proper construction method. A research by Gibson (1979) found that while most building defects are associated with the structure, others are associated with unsightly patterns of soiling of the elevations and lack of accessibility to services. Whereas, for a building not more than 25 years old, Ranson (1981) showed that design faults and specifications comes the second after the wear and tear factor.

Assaf *et al.*(1996) identified 11 major groups of faults; they are, the defects in civil design, architectural defects in design, design defects in maintenance practicality and adequacy, defects due to consultant firm administration and staff, defects due to construction drawings, defects due to construction inspections, defects due to civil construction, defects due to contractor administration, defects due to construction equipment, defects due to construction materials and defects due to specifications.

The English Building Research Establishment conducted a survey of building failure patterns and their implications. Based on their study on a sample of 51 buildings, 58% of the defects originated from faulty design, 35% from faulty execution, 12% from faulty materials, components or proprietary systems and 11% from unexpected user requirements but there was some overlap among these categories (Seeley, 1987).

3.3 The Effects of Design Defects on Maintenance

According to Assaf *et al.* (1996), defects in civil design include in inadequate provisions for structure movement, ignorance of aggressive environment and weathering conditions, ignorance of biological effects, load impact on structural stability, ignoring on wind effects on structure and improper conduits locations and pipe openings at critical structural locations.

The UK Committee on Building Maintenance suggested four main reasons for the existence of design defects in buildings :

(i) Inadequacy of the client brief ; the architect as a professional is expected to assist the client in developing an adequate brief
(ii) Inadequacies of design ; most design errors are errors of specification, or choice of materials, juxtaposition of incompatible materials or components and inadequate provision of safe access for maintenance
(iii) Construction errors due to ambiguity or inadequacy of specification or supervision
(iv) Defects in materials and components

These reasons stem, in the main, from the direct actions or omissions of the designer, and are responsible for 20% of the annual cost of repairs in the United Kingdom.

Out of the above four factors, Ahmad (2003) stressed out three major aspects that can be linked into design defects in the context of Malaysia scenario. i.e. the shape or form of the building and its components, choice of materials or finishes and construction techniques to suit the design.

3.3.1 Shape or Form of the Building

Taking Petronas Twin Tower and Menara Telekom buildings as examples, they are appreciated buildings and have gained high salutation for their aesthetics. Directly we could not label them as defects design due to the fact that they are designed beautifully and appear to be very attractive landmarks. But from the angle of maintenance works, it is difficult to maintain the façade with such irregular building shapes. The question is, are they equipped with appropriate and sufficient equipments and fixed permanently to the building to ensure the facades are always clean? If so, how much maintenance works will cost the management as compared to maintaining a regular type of design.

This problem will be aggravated with the problem of water seepage or leakage due to poor workmanship, especially when the building facades are made up of thousands of interfacing parts, in which each intervening joint is susceptible to some form of failure. Problem associated with water tightness occurs when there is a shortcoming in the design concept, defective workmanship, or inappropriate materials used. According to O'leary, (2003), conceptual failure is one where the designer would never have worked no matter how excellent the materials used or how skilled the artisan who installs them.

3.3.2 Choice of Materials or Finishes

Most of the problems normally encountered are roof systems, which due to their design complexity, pitched or flat roofs are prone to leak. These problems basically are

the result of insufficient data and information that can support design inputs, inexperienced designer or a failure to obtain a good design team to advise for the proper from of building features. Whilst the use of inferior or poor building materials can cause significant problems such as windows failing to perform and function adequately, rapid degradation of materials over time and due to climatic changes, short life spans, using rare materials that are difficult to substitute when the existing one damaged or lost due to wear and tear. The design configuration and workmanship may have been adequate if the proper materials had been used. Sometimes, the contractors or craft men stray from the properly specified materials through ignorance, but more often as an expedient to save time or money without realizing that an unsatisfactory result could ensue.

3.3.3 Construction Techniques to Suit Design

Construction techniques or deficiencies can be linked to design because of its needs to achieve intended form of building or construction process that determined by the designers. Some examples of the deficiencies is very much illustrated in the prefabrication design systems and site services concept. In the prefabrication systems, the joint of one construction panel to another is always the source of leaks, especially at the roof parts or in the bathrooms. Actually, this system is not a good construction technique for Malaysia in which the use of water at home is quite excessive. Although correction measures are taken, but it always lasted for a limited time period. Instead, an expert should be sought who understands the design problems inherent in the failed system, whether it happens to be roofing, water proofing, jointing and so forth (O'Leary, 2003).

Like United Kingdom, Malaysia is fortunate to have plenty of historical buildings which contributes much to tourism industry. On the other hand, being a developing country with quite a huge capital resources, it is developing quickly in every area, including building construction. Various types of buildings, especially sky-scrapers with different purpose and objectives have been erected. Having the aged, valuable buildings to be preserved to ensure income generation through tourism industry continues, as well as the new, high-technology based buildings to be taken care of to ensure prolonged building life span, it is a big challenge to Malaysia.

Previous overseas researches have proven that design factors and construction factors are the key elements that contribute to the speed of building deterioration. Large and complex projects have been built due to the demands of both the public and private sectors. To meet the high demand of both sectors' needs, it is expected that many errors and defects will have occurred during the design and construction stages of these projects, later resulting in higher maintenance cost. Under normal conditions, all buildings begin to deteriorate the moment they are constructed and maintenance is needed to keep them in good condition. A large amount of the country's maintenance resources is being expended on corrective or remedial measures to buildings and their services due to design or construction defects. For example, it has been reported that the amount of money allocated to do repair works at the Malaysia's prime minister's official resident building in Putrajaya, reaches RM6 million. Hence, reducing the number of design and construction defects will result in the reduction of maintenance expenditure (Gibson, 1979).

Other studies have found that while most building defects are associated with the structure, others are associated with such things as unsightly patterns of soiling of the elevations, lack of accessibility to services or simply due to wear and tear. Different study would come up with different parameters which contributes to building defects.

Arditi and Nawakorawit (1999a,b) have listed 22 sources of the major maintenance-related complaints on building defects that designers and property owners each, reported receiving from clients. The complaints are categorized in 5 groups :

(i) Safety
(ii) Design quality
(iii) Maintenance
(iv) User comfort
(v) Building services

Results from the survey show that complaints on user comfort become the clients' number one concern followed by maintenance. Design quality category was almost not in their list as most clients (and designers themselves) believe building design and building operation/maintenance are entirely separated and both building owners and designers did not consider serious enough.

Therefore, in Malaysia scenario, it is important to gather sufficient information on complaints forwarded by clients and under which category the complaints made would fall into. This is to ensure careful justification on high priority action during the design and the management of buildings in order to minimize and correct these faults.

CHAPTER FOUR

DESIGN AND MAINTENANCE

4.1 The Role of a Designer

An important part of the role of the designer is to enable creative solutions latent in and conceived by the client or community to emerge. Such a designer, while becoming closely identified with the goals and objectives of those for whom he works, retains the distinction of having powerful specialist tools and techniques at his or her command. These relate to the imaginative expression of latent solutions, simulation and prediction of consequences in terms of technology and resources. The designer should be able to predict the ultimate effects of a proposed design scheme to user and society as a whole so that the objective of satisfaction and value for money can be achieved. He should be fully aware of the good and bad effects of designs on certain issues which are important to users even though to the developer, it is of no financial interest. Another word, awareness of the responsibility to carry out social obligation.

Somehow, sad to say, many designers only consider the interest of who pays for the fees as ‘the only client’, particularly in cases of housing developments for sale. The

consequences of such attitude can be fatal to building users in later years and will only rebound ultimately on the reputations of both client and designer (Miles and Syagga, 1985).

4.2 Total Building Maintenance

According to a report by UK Committee on Building Maintenance (1980), 20% of the annual cost of repairs in the United Kingdom are due to design defects. Meaning, 80% of the remaining of the cost of repairs must be attributed to the normal wear and tear of the building fabric. At first sight, normal wear and tear is inevitable, by definition and the designer may expect to be absolved from any responsibility for these costs. However, while there is a limit to the extent to which the designer can forecast, much less control, the use of the building, this should not overshadow the fact that the designer cannot really escape responsibility for maintenance whether regular or abnormal as he has rationalized the future outlook of the building.

Furthermore, it is not always easy to draw a distinction between the cause of a defect and normal wear and tear. For instance, it is not technical detailing alone that may cause rapid deterioration of the buildings when compared to the effect of density or intensity of use or aspects of space requirements. These aspects may be attributed to conceptual design rather than draughtsmanship or detailing. It is often assumed that errors in detailing arise because the designer leaves the details of his vision to be worked out by draughtsman who are technically unqualified and may arrive at solutions which turn out unsatisfactorily. Although this is a possible source of maintenance problems, good detailing is an integral part of good design and the designer should

check working drawings carefully before they are issued so that faults are identified and corrected before the construction phase (Miles and Syagga, 1987).

4.3 Involvement of Maintenance Personnel during the Design Stage

Communication has often been the problem in many issues and it is especially true in the building and construction industry. The combined efforts and ability to work together between many professions and trades, both skilled and unskilled together with the knowledge to read, understand and interpret architectural drawings is of prime important to ensure success of the completed building.

Unrealistic and impractical design or design details can contribute to the lack of quality and to high maintenance cost. This problem can be reduced or avoided if there is a better understanding between the consultants and the owner or his representatives (Ahmad, 2003). In an organization, an opportunity is available for the consultants to open their doors and allow an experienced maintenance manager to be part of their design team for that particular project. The presence of the maintenance manager from the preliminary design in the architect's office does not have to be on full time basis. It doesn't mean that the maintenance manager want to control the consultants in a way that infringes on their professional responsibilities, nor does it mean that the staff/client is changing the contracting method to pure Construction Management services, but are trying to work as a team from the very beginning so that they are aware of design decision made. They are also able to make maintenance problems known to the design team at very early stage of design process and to inform them of the consequences because they are the experts who know more about the maintenance problems, strength and weaknesses and their maintenance method.

4.4 Link Between Design and Maintenance

The understanding of a good building design always relates to the shape of the building and its appearances. In many occasions, this perception has neglected the actual function of why the building was built in the first place. The inability of the building to serve its purpose has automatically ignored by the public because of the exotic and attractive design of the building without even considering for economic reasons, or for safety, usability and maintainability. The more unique a building is being designated, the more it would gain artistic value, thus appealing and very much appreciated. Most people look only for its form and shape to regard it as a good designed building rather than considering its proper function and performance as needed by the occupants. Without much objection, designers tend to spruced-up their buildings above ground with various shapes, some with spiraled forms, inclined, distorted, top heavy shaped and so forth which encourages high cost of maintenance (Ahmad, 2003).

Nowadays, designers tasks are a whole lot simpler and at ease with various types of design software available in the market. Little data is required to enable them to come up with a good design as required. Natural resources such as wind and sunlight can always be substituted with air-conditioning and electrical lighting. Buildings do not need large windows or more air ventilation as before and its space can be fully utilized to the maximum (Ahmad, 2003).

However, the consideration of design impact onto building after completion is almost neglected. The difficulties in maintaining the building after completion also have almost never been taken into account, especially at the time the building proposed to be built. As a result, cost to maintain the building increases, its life cycle declines and more parts of the buildings easily deteriorated. A research by Arditi (1999) has shown that design plays a major role in determining the condition of buildings after completion,

especially in the aspects of defects and maintenance. Indirectly, design influences the performance and physical characteristics of the building and its durability to stand against environmental elements, noise and social interferences such as graffiti and vandalism. Therefore, the link between design and maintenance should not only be seen from the point of increasing number of repair works or cost involve, but it needs to consider also the impact of a design on structure and materials installed as well as the life cycle for each of the components or elements of the building.

4.5 Characteristics of Building Design

According to Ahmad (2003), the surrounding environment, the needs and characteristics of its users and climatic conditions mostly influences traditional building designs. In this context of traditional Malaysian buildings, its design characteristics are capable of solving user's living needs and all related environmental requirements. Unfortunately, some of overseas trained designers have different approaches and sometimes export too much of their overseas design knowledge into local design product or blindly incorporating overseas design concepts for the local usage. This is true due the fact that in many occasions designers will design a building based on whatever he had learned from his training or overseas experiences or make references to the secondary sources that are mostly produced by outsiders (Ahmad, 2003).

Although designs are more concerned with client requirements and the actual building objectives, but in reality designers inevitably have to accommodate his design idea to the needs of the surrounding environment that will include human settlements and ground conditions as well. Certain factors such as community facilities, accessibility, inter-relationship among users or residents and surrounding land use need

to be considered in the design. These requirements are important because settlements like cities are self-regulating systems created for the benefits of humans and their sustained livelihood. Their inhabitants collectively attempt to keep their constant comfortable state when faced with internal or external change (Girardet, 2001). Within the settlement, buildings become part of the system and as a place for living and working buildings are only functioning when the surrounding systems support other activities. Therefore, a designer should not isolate his design from considering the role of other buildings and its surrounding developments, especially when the surroundings could provide better information and good tips of the local needs or building conditions.

Sometimes there exist a number of design defects and construction flaws but since there are no feedbacks or complaints about the projects after they were used, this seems that users are satisfied and felt sufficient to whatever had been built for them. After all, in the final analysis it is not the design statement that is most relevant, nor the success or failure of the designer in realizing his goals but other methods for generating valid and shareable information from completed projects, especially in terms of getting feedback from previous projects for future benefit and improvement.

In many cases, there are incidents that designers do not care much about certain factors or the effect of design on the building after completion, for example building maintenance as compared to other categories although, the design stage is a critical stage in the life cycle of a building in as much as most critical decisions are made at this stage. According to a survey by Arditi and Nawakorawit (1999), building owners claimed they had some informal or formal communications with design firms during the design process. Somehow half of them claimed that designers never returned after the buildings were operational to assess the performance of the buildings they designed. This happened probably because the client is not the final user of the building and sometimes has little understanding of the problems of the particular building in use.

To look beyond the physical structure of a building to its social consequences, to the sorts of people and activity it will contain, and so its effect upon the surrounding community is a necessary aspect of a good design (Sommer, 1972). Other than that designers or designers' need to understand the impact of their design decisions upon indoor air quality, occupants' health, comfortability, energy consumption and local needs and without this knowledge, he or she cannot produce a good building design.

4.6 Design for Ease of Maintenance Concept

The term 'design' according to Gropius (1970), embraces the whole orbit of man-made, visible surroundings, from simple everyday goods to the complex pattern of a whole town. We can establish a common basis for the understanding of design by reaching through objective findings rather than through personal interpretation. It should apply to any type of design, for the process of designing a great building or other things. Theoretically, the process of designing a building can be seen as assimilating all the relevant facts, grading them in terms of priority, analyzing their relationship, forming conclusions as to their interaction and arriving at a logical solution which satisfies all condition (Barritt, 1982).

Ease of maintenance concept which is also known as maintainability, was formally initiated by the military services of the United States in 1954 (Blanchard and Lowery 1969). According to BS3811 (1984), maintainability is

"the ability of an item, under conditions of use, to be retained in or restored to a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources."

Dunston *et al.* (1999*)* defined maintainability *as*

"the design characteristic which incorporate function, accessibility, reliability and ease of servicing and repair into all active and passive system components, that maximizes costs, and maximizes benefits of the expected life cycle of a facility."

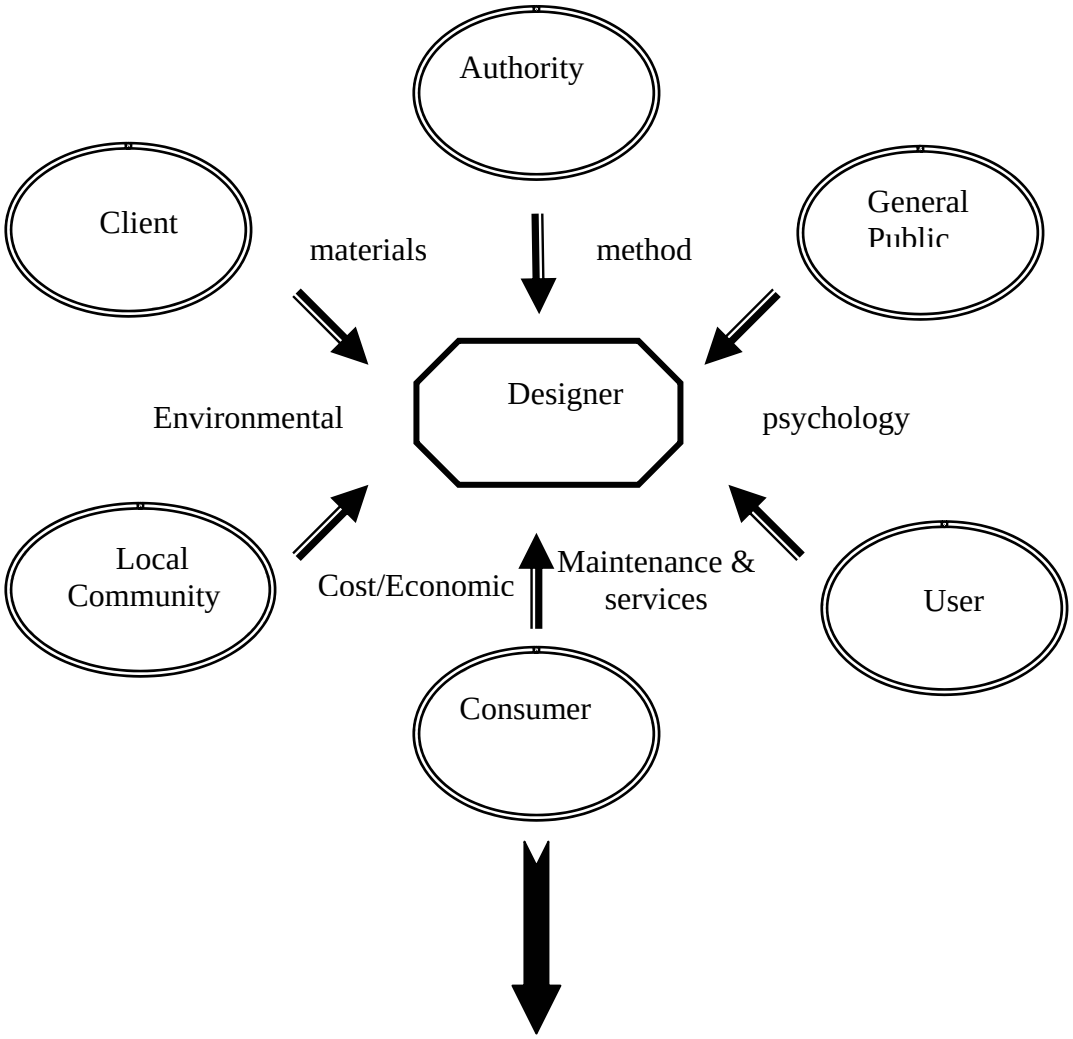
The notion of ease of maintenance concept has been manifesting during the past decades as building owners are confronted with soaring maintenance costs (Bourke and Davies; 1997, Underwood and Alshawi; 1999, Shohet *et al*.; 2002). The huge amount of maintenance cost can be reflected in the increasing number of failings attributed by design defects (Al-Hammad *et al*., 1997), substandard construction workmanship (Assaf *et al.,* 1995) and incompetent maintenance practices (Ardit and Nawakorawit 1999a, 1999b). This trend is due to the growing complexity of the buildings, the increasing proportion of systems in them, higher level of service and the higher portion of maintenance costs in the life cycle costs of buildings (Chew *et. al,* 2004).

4.7 Design Considerations for a Quality Building

Over the years, it has been proven that the selection of the correct design, coupled with the correct choice of materials and systems have long term effects on the performance of a building (Cartlidge, 1976). This assessment usually involves an inspection by the building surveyor to determine the effect and consequences of a design on a building after completion or as post occupancy evaluation. To do this it is necessary to know the expected performance and design standards of a building. Many of the design characteristics of buildings are direct outcome of design decision, or the quality of the construction that transpire design choices.

In the process of designing a building a good designer must be able to consider various factors and categories to enable buildings become quality product that consumers can utilize at the maximum satisfaction. A building should not be looked only from the aspect of aesthetic or its function because the product of quality building design is a creation to provide a comfortable working environment and living activities. Designing a building must satisfy the input and outputs requirements that consist of real things and psychological needs (Ahmad, 2003).

Before a product of building design can be achieved there are two basic requirements that must be analyzed as design inputs, i.e. external and internal inputs. Factors such as client, user, general public, local community, consumer and authority can be categorized as external inputs, whilst, internal inputs are environmental considerations, materials/equipments, maintenance/services, methods/technologies, cost/economics and psychological needs (refer to Figure 3.1). It is only then that good building design is achievable to produce quality output, which consists of excellent building performance, aesthetic values, longer life span or cycle, rehabilitation, comfort and safety and health conditions (Ahmad,2003).



Building Performance	Aesthetic Value
Longer Life Span	Rehabilitate
Comfort Ability	Health & Safety

Figure 4.1 Design considerations for a quality building (Ahmad, 2003)

4.8 Operational Lessons as Data for Feedback

According to Dunston and Williamston (1999), one of the best methods to avoid the same mistake from repeating in the future projects are incorporating maintainability or design for ease of maintenance concept into constructability process. This will give significant impacts to improve design processes. Development of a best practices database model that employs the values of 'lessons learned' throughout the design and construction phases will allow for improved operation and maintenance of buildings as well as allow improved assessment of future facilities. Figure 4.2 illustrates the paths by which the best practices information may be made available to support the project development process, especially during the early design stage.

The design guidance captured and stored in the proposed system is stated in a manner that avoids the violation of proprietary interests. An initial compilation of such information for designing building envelope systems has captured and phrased to focus upon material properties and construction methods (Williamson, 1996).

Furthermore, the common concern for liability associated with documenting lessons learned can be avoided if the recommendations are not documented with the specific cases from which they are derived. Therefore, the database model should be developed on web-based platform and the preferred host is a long standing institution such as university or professional society like IEM. In effect, the system would become a digital library where information obtained and contribution can be accessed by all parties involved in the design, construction and maintenance field.

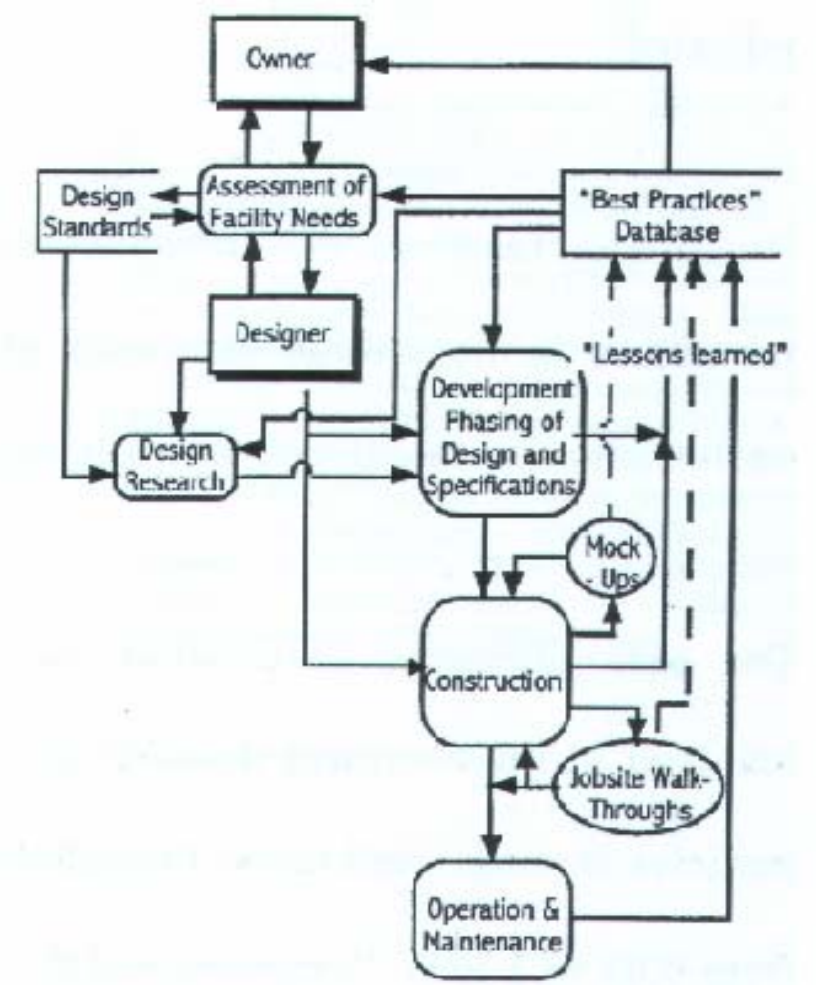


Figure 4.2 Proposed design/construction maintenance feedback (Dunston & Williamston, 1999)

The design of a building is a process that involves the consideration of a variety of factors. Arditi and Nawakorawit (1999) listed out 22 factors according to the importance and were grouped into 5 classes; safety, design quality, maintenance, building user comfort and building services. The survey showed that out of the 22 factors, maintenance category rank the 17th, 21st and 22nd in the order of importance. It

appears that maintenance is not at the top of building designers' priority lists when they design buildings. This is probably because building owners often place undue emphasis on initial cost and ignore the periodic cost of upkeep, inspection, repair and replacement. On the other hand, among the complaints designers report receiving from clients and tenants, factors such as ease of repair, access to cleaning area and ease of cleaning appear to be ranked much higher in the order of importance. Designers should be more sensitive to these issues instead of just claiming to have better knowledge in maintenance issues and despite sending their personnel to maintenance training and seminars.

It is time that building owners and designers work together hand in hand with maintenance consultants, seeking their expertise in future projects. These maintenance consultants must be dissolved in the schematic and preliminary stages to contribute relevant views and opinions and to give feedback to ensure the assets will be preserved, can be preserved on long term basis with minimum maintenance expenditure. Therefore this study was carried out to assist designers in identifying maintenance related problems due to insufficient design factors.

CHAPTER 5

RESEARCH METHODOLOGY

5.1 Introduction

This chapter elaborates the process that was conducted in fulfilling the objectives of the project. It also discuss about the data requirements, data collection and selection, the selection of case study area and the accuracy consideration.

This research was carried out so as to identify building defects that are related to poor maintenance consideration during design stage, to identify design maintenance factors and to propose critical maintenance factors need to consider when designing for maintenance guidelines for buildings.

This study began with a theoretical or applied research problem and ended with empirical measurement and data analysis. The first step in conducting the research was identifying and locating research problem. At this stage the researcher collected as much facts as possible on the problem and list out possible explanations to the problem.

The significance, objective and scope of the study were identified and established during this stage.

After identifying the problem for research, the researcher had to select the appropriate research design. In this study, in-depth investigation had been carried out to describe, compare and evaluate the problem by collecting, compiling and interpreting factual information.

5.2 Literature Review

Understanding the existing body of knowledge is vital for the research process. Exploratory search of the literature provides guidance to the initial selection of the research problem and providing the background knowledge to the researcher. In this study, the information sources were gathered out from:

5.2.1 Text Based Materials

Text based material such as ASCE journals, local proceeding papers and text books were used in this study.

5.2.2 Preliminary Interview

Interview sessions took place through telephone conversation between the researcher and potential respondents when calls were made to maintenance firms' offices and designer firms' offices. Calls were made in order to get permission from them to answer the questionnaires. In the interview sessions, questions regarding their nature of jobs and responsibilities which included their scope of work were forwarded. This was a very helpful stage for it gave the direction and assisted the researcher in generating new ideas to develop the questionnaire.

5.3 Research Setting

To achieve the objectives of this research, the most effective way is to distribute questionnaires and conduct interviews. Therefore short interview sessions were held with 10 designers from the selected consultant companies that involve in the design of office buildings. The location chosen was within Shah Alam and Klang Valley. Whereas short interviews were conducted only on companies around Shah Alam and Subang Jaya, which is to the nearest.

5.3.1 Develop Questionnaire

The questionnaires presented in the Appendix A and Appendix B were used for the purpose of this task. The questionnaires were based on those developed by Arditi and Narakorawit (1999), with a small amendment made to suit the local trend. The questionnaires were divided into two categories:

5.3.1.1 Maintenance Firm Questionnaire

The questionnaire primarily sought to find out the most frequent defects complaints received from the building users and defects encountered by the maintenance engineers/personnel during routine inspection and what are the factors they think relevant to be forwarded to design practitioners. The questionnaire was divided into two sections:

(i) Section A : General information on the maintenance organization such as services offered, numbers of employees, type of building maintained and average size of building maintained

(ii) Section B : Information on the maintenance works such as types of complaint received, building materials used, repairs and replacement works of building components, involvement in design works and degree of difficulties in inspecting different building components

Respondents were also asked to rate the identified 22 maintenance factors (which have been grouped into 5 categories) according to the degree of importance. The suggested scores were : extremely important (5), very important (4), somewhat important (3), not very important (2) and not important (1).

5.3.1.2 Designer Firm Questionnaire

The purpose of this questionnaire is to identify the criteria designers commonly look into before designing a building and their level of knowledge with regards to building maintenance factors.

The questionnaire was also divided into two sections:

(i) Section A : General information on the maintenance organization such as services offered, numbers of employees and type of buildings designed
(ii) Section B : Information on the design aspects such as engagement of building maintenance experts during design phase, frequency of meeting with building owners to inspect on complaints by users, level of maintenance knowledge and criteria when selecting building materials

Respondents were also invited to rate the identified 22 design factors (which have been grouped into 5 categories) according to the degree of importance. The suggested scores were : extremely important (5), very important (4), somewhat important (3), not very important (2) and not important (1).

The collected data were analyzed using the Statistical Package for Social Science (SPSS) software, thus allowing credible inferences to be drawn from the information provided. The questionnaire assisted the researcher in time speed for data completion and analysis, accuracy and compatibility. Considerable effort was made to keep the questionnaire simple, clear, short and at the same time able to obtain as much information as possible. The covering letter accompanying the questionnaire was also carefully prepared to create an impression of professionalism in the survey.

5.4 Post Questionnaire and Interview

There are various methods to distribute the questionnaire and the researcher had used some of the methods in order to get as fast as possible the feedback from the respondents.

After identifying and collecting as many as possible the company addresses and their phone numbers, the researcher called the company to get permission to distribute the questionnaires and conduct interview. After getting the permission, the questionnaires were sent to 91 companies comprises of consultant firms and maintenance organizations (including those without calls) by mails, emails, facsimile and by hand. Face-to-face interview were conducted on the respondents around Shah Alam and Subang Jaya when the collection were made about three weeks later.

5.4.1 Problems and Limitations

The time frame to all the process of getting response was four weeks. Somehow, after three weeks, questionnaires have yet to be received , the researcher did some follow ups either by calling to remind them or went to the nearby offices to collect the questionnaires by hand. At the same time the researcher took the opportunity to carry out face to face interview with the respondents.

Problems that occurred during this stage can be presented as follows:

(i) Some of the respondents responded to all questions half-heartedly

(ii) Some questions are left unanswered or wrongly answered

(iii) The respondent's refusal to complete the questionnaire or to be interviewed.

(iv) The respondents gave various excuses not to be cooperative for their non-participation. For example, it is against their company's policy, lack of time (too busy), lack of interest and matters of confidentiality or sensitivity.

(v) Most of the time, upon receiving the questionnaires, respondents tend to shove aside the questionnaires to be looked into later and completely forgot all about it until they received call of reminder from the respondent.

5.5 Data Collection and Analysis

This had been a very important and crucial stage of the research study, as it described the results of the raw data collected from the respondents. At this stage the results and data were analyzed using frequency and average/mean analysis in order to get an accurate result.

Data obtained from the interviews and questionnaires feedback were presented in the form of table, Bar Chart , Pie Chart and Graphs to generate findings. Here, the data had been converted into percentages to make findings more understandable.

5.6 Validation of Recommendation

During this stage, the researcher contacted the respondents and expertise in both the construction and maintenance fields to validate the recommendation. In order to avoid the researcher's recommendations do not match with the respondents actual requirement.

5.7 Conclusion

Conclusion were made based on the analysis of data obtained from literature review, respondents and discussions.

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Introduction

In this chapter, the results of the study are discussed. 100 questionnaires were distributed to designers and maintenance firms respectively in order to identify building defects that are related to poor maintenance consideration during design stage and to identify design maintenance factors in civil and architectural designs,. The targeted group was the managers, head of departments, architects and engineers of the designers and maintenance firms. By the cut off date, the researcher managed to collect 68 feedbacks, out of which 30 came from maintenance firms and 38 from designers. This constitute a 30% and 38% response rate respectively. According to Fellows *et al.* (1997), the normal expected useable response rate is ranging from 25% to 35%. Therefore, the total feedbacks received managed to provide sufficient data for this research.

The questionnaires presented in the Appendix A and Appendix B were used for the purpose of this task. The questionnaires were divided into two categories of

respondents, the maintenance firms and the designers. The results of the survey are presented in tables and figures.

6.2 Maintenance Firm Questionnaire

The list of maintenance firms were gathered from various building owners with different nature of business i.e. hospitals, residential, offices and commercials as well as friends who work in the maintenance sector. These firms were recommended due to the fact they carry out the maintenance jobs in the owners' buildings.

6.2.1 General Characteristics of Respondents

Question 1 until 6 were asked to collect the characteristics of the maintenance firms. Because the survey was conducted on selected respondents, which are semi large-sized and medium-sized firms in Malaysia, the answers gathered were in accordance to the researcher's expectations. Answers in Question 1 indicate that out of 30, 17 (56%) of these firms employ more than 20 employees whereas 37% employ between 11 to 20 employees. Only 2 out of 30 firms employ less than 10 staffs. Some firms may have many regional offices or branch offices located throughout Peninsular Malaysia and it is possible that firms that are reported as small sized companies are in fact branch offices.

Question 2 explores the depth of the firms' experience and tenure in the industry. Because the firms constitute quite large and medium sized firms, all of them have been expected to be in business for more than at least 1 year. According to feedbacks, 50% of them have been in business for not more than 20 years whereas the other remaining 50% have been in business for 1 to 10 years.

The answers to Question 3 indicate that more than half (54%) of the firms own most of the building they manage, whereas only 23% mostly manage buildings that are owned by other organizations. The remaining 23% indicated that some of the buildings they manage are owned by their firm and some by others. This shows that 16 out of 30 respondents are property management firms, they themselves act as building owners.

Most of the responding maintenance firms offer more than one service. For Question 4, maintenance-related services offered by the maintenance firms are mainly on repair and replacement works with 23% of the respondents, inspection and renovation works each with 23%, cleaning at 22% and other facilities like landscaping and transportation with 7%. Maintenance consultancy ranks the lowest at 2% only. Probably this is because at present, most project owners always tend to overlook the necessity of having maintenance consultation in the early stage of the project.

Question 5 asked the respondents to determine the source of services offered by their firms. The answers indicate that 41% of the respondents use in-house services for some activities and outsourcing for others, 31% provide all services with in-house capabilities and the remaining 28% rely on complete outsourcing for all services. Analysis of the data with respect to building ownership shows that if a firm does not own the buildings managed by the firm, services are mostly outsourced. According to Arditi and Nawakorawit (1999), the uncertainty associated with a maintenance company's contracts with building owners forces the maintenance firm to pursue a

policy that can free them from any agreements with outside sources in the event their contract is terminated by the building owner. This policy is apparently preferred to cycles of hiring and layoffs of permanent personnel in response to cycles of winning and losing contracts with building owners (Arditi and Narakorawit, 1999).

Question 6 determines the number of buildings that responding maintenance firms were managing at the time of the survey. 56% of the firms are managing up to 20 buildings whereas 17% of them manage less than 10 buildings. The least number of buildings which is below 5 is being managed by 27 % of the respondents. This distribution is to be expected because the list of respondents selected come from semi large firms.

Question 7 explores the factors that maintenance firms consider before deciding whether they should manage the maintenance of a building. The distribution of the answers is presented in figure 6.1.

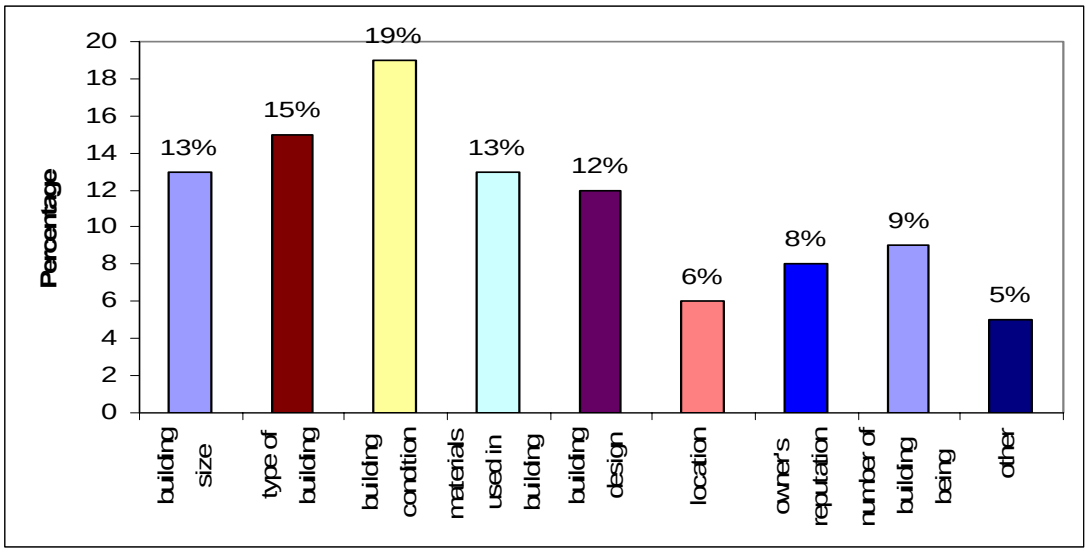


Figure 6.1 Factors in managing building maintenance

The top three factors that the maintenance firms consider are : firstly, building conditions (19%), secondly, type of building (15%) and thirdly, materials used and building size (13% respectively). It seems that maintenance firms are very cautious in selecting buildings probably due to the fact that not all maintenance companies have full experience in handling buildings which are old, outdated or advanced technologically equipped. Also, every type of building has its special own characteristics, for example, managing a sports stadium requires expertise that is not typically offered by a firm that manages only office buildings. Materials selection too play important role, materials which are easily obtained from local markets will enable maintenance firms to speed up repair and replacement jobs assigned to them in order to avoid any backlog on work. Because time is an essence here, delay of jobs will only cause payment from owners to maintenance firms to be deducted and furthermore, it will affect the firms' reputation to the eyes of all. Finally, maintenance firms which employs many staffs or having many subcontractors may not have problems to maintain buildings which large gross area.

6.2.2 Characteristics of Managed Buildings

Question 8 until 10 were designed to determine the characteristics of the buildings managed by property management firms. Some of these characteristics served as control groups in the analysis of the remaining data.

The age of a building is one of the factors that maintenance firms do not really consider when selecting the buildings they want to manage. The answers to Question 8 show that half of the respondents (50%) do not differentiate between younger and older buildings, whereas 30% manage relatively older buildings that are more than 10 years and the remaining 20% choose to manage buildings that are less than 10 years of age.

In response to Question 9, 47% of the respondents reported that the buildings they manage are in average condition, 27% say the building they manage are in good condition whereas 23% of the respondents agreed that their building condition is very good. Only the remaining 3% reported very poor building condition. It is observed that the condition of older buildings (constructed more than 10 years ago) is slightly better condition in general compared to the newer buildings (refer to Table 6.1).

Table 6.1 : Number and age of building managed by maintenance firms

		Age of buildings the maintenance firm is managing			Total
		Relatively new buildings (Less than 10 years old)	11years old buildings and above	Combination of the above	
Number of buildings managed by maintenance firm	Fewer than 5 buildings	3	3	2	8
	6-10 buildings	1	0	4	5
	11-20 buildings	2	6	9	17
Total		6	9	15	30

According to the answers to Question 10, more than half (57%) of the respondents manage a mix of large-medium-small sized buildings. Whereas 20% of the maintenance firms manage large and medium sized buildings respectively. It is interesting to know that only one respondent which gives the remaining percentage of 3%, manages a small building, assumable its own building (refer to Figure 6.2).

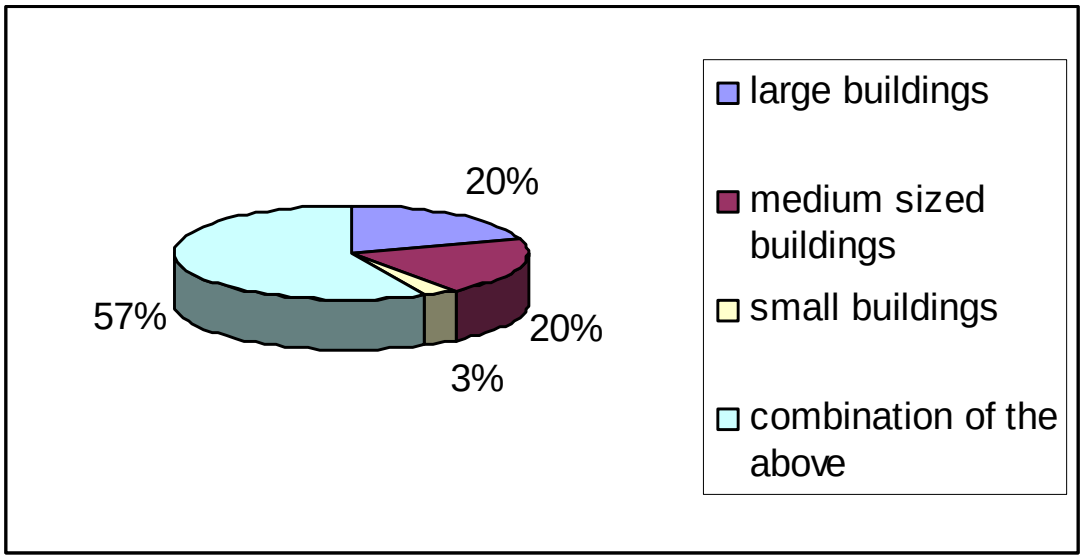


Figure 6.2 Size of buildings managed by maintenance firms

6.2.3 Maintenance-Related Problems

The extend to which maintenance is considered at the design stage is likely to depend on whether or not the owner or the person commissioning the building will be the subsequent user. When the owner is the developer who intends to sell or lease the building upon completion, probably maintenance will be considered only if it will likely to affect the sale price or rent. Even when the owner uses the building for own need, probably the initial capital costs of the building and the subsequent maintenance costs will be drawn from different sources and not related. However, both new construction and maintenance will definitely face financial constraints and in order to balance up the costs between them, proper analysis must be made to improve the efficiency of the project starting from early start of project. In this case, preferably during design stage.

Somehow, for maintenance side, the maintenance firms should consider collecting and analyzing the comments made by building users to improve their services as well.

Question 11 was asked to identify the maintenance-related problems that maintenance firms experience. The distribution of the answers is presented in Figure 6.3. Analysis shows that poor construction quality gives the most problem to maintenance firms (24%), closely followed by building design deficiencies (20%), poor performance of the contracted firms (19%) and not enough staff (15%). Figure 6.3 shows that almost half (44%) of the problems that the maintenance firms are currently facing are caused by inadequate design and construction processes (building design deficiencies and poor construction quality). If one can prevent these problems especially during the design and constructed processes, almost half of the maintenance-related problems could be eliminated.

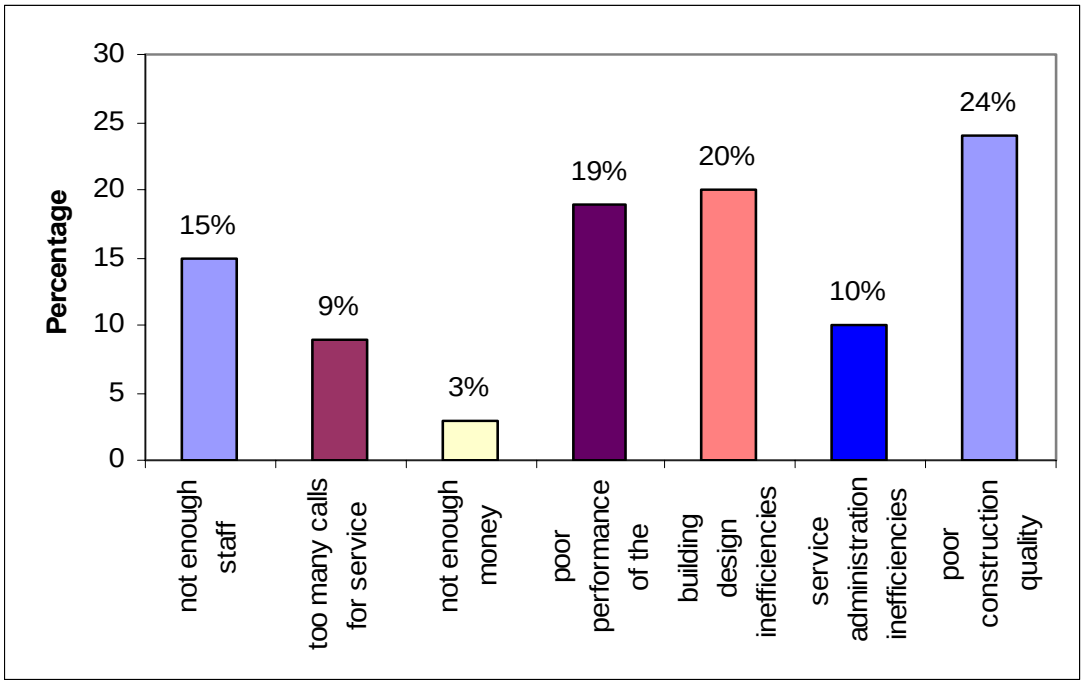


Figure 6.3 Problems faced by maintenance firms in building maintenance

In spite of not having enough staff, a study by Arditi and Narakorawit (1999) shows that the number of calls for service and the size of the maintenance staff increased respectively. Therefore, maintenance firms would be able to keep maintenance–related complaints stable despite an increase in maintenance calls by increasing the size of their staff. Or alternatively, to practice the selective outsourcing whereby selective outsourcing refers to the use of contractors to perform some of the services, and at the same time, hiring an in-house maintenance staff to provide other selected maintenance services. The choice between employing hands-on-the work-staff directly to execute maintenance work or engaging an independent contractor for that purpose should be decided according to which offers more advantage in terms of cost, quality, convenience and time speed (King *et al*., 1984, Lee, 1987, Holland, 1987). These advantages and disadvantages should be weighed in relation to factors such as nature of work, volume of work, response time, location, quality, security, availability of space, market condition, cash flow and total costs (Lee, 1987).

Question 12 was created to determine the maintenance-related complaints that the firms have received from building users. According to the results presented in Figure 6.4, repair and replacement is the area most often commented on by building users. It is probably due to its visibility to the eyes and the way it relatively affects the function of other system of the building. The complaints that were listed in Question 12 are categorized in five groups :

(i) Design quality – includes functional layout, choice of equipment and choice of materials

(ii) Maintenance – includes cleaning, repair/replacement and access to cleaning areas

(iii) User comfort – includes air circulation, indoor air quality, humidity control, heat loss/heat gain, lighting, human traffic, vertical transportation and noise protection.

(iv) Building services – includes clean water supply, wastewater disposal, garbage disposal and telecommunication

(v) Safety – fire protection, structural constraints, construction methods and security

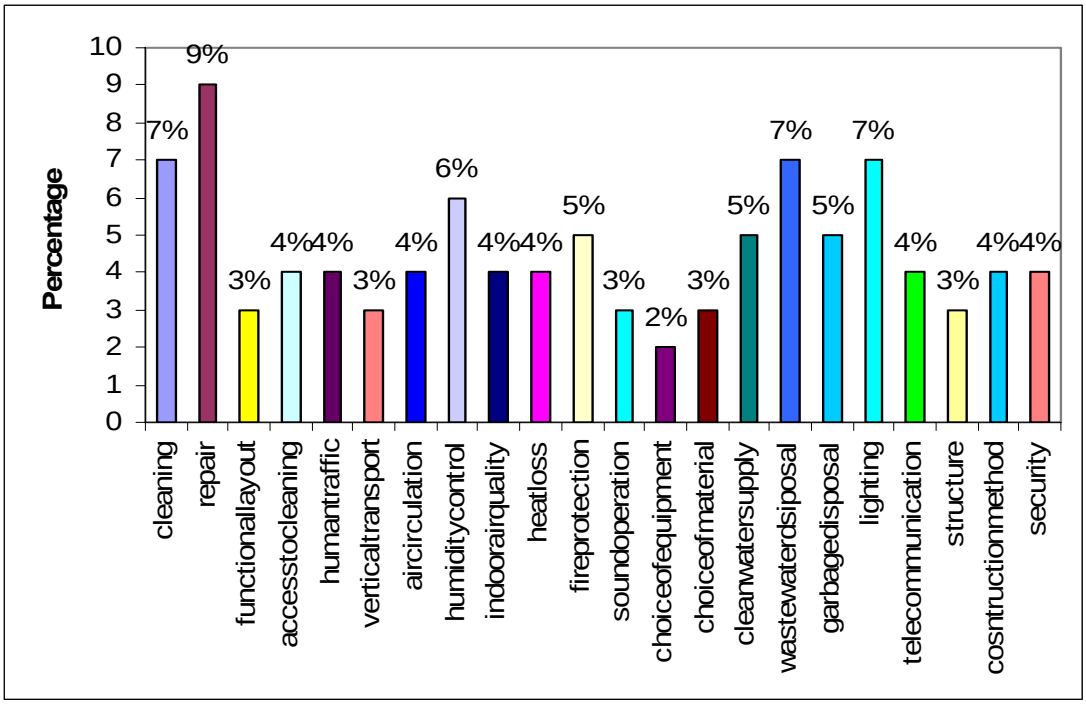


Figure 6.4 Complaints received from building users

According to analysis in Figure 6.4, complaints of repair and/or replacement works (under maintenance category) come in at first place with 9% in the list of complaints by building users. Following closely are cleaning works (maintenance), waste water disposal (building services) and telecommunication (building services) at 7% respectively, 6% on humidity control (user comfort) and 5% on fire protection (safety), clean water supply (building services) and garbage disposal (building services) respectively. Whereas factors like access to cleaning areas, human traffic, air circulation, indoor air, air quality, heat loss, telecommunication, construction method and security were reported by 4% of the respondents. Functional layout, vertical

transportation, choice of material, sound protection and structural complaints were reported by only 3% of the respondents and finally, only 2% answered choice of equipment which is under the design quality category.

According to summary in Table 6.2, user comfort appears to be the number one concern of building users with total response rate of 35% whereas building services is the second most mentioned complaints with total response rate of 21%, maintenance at third place with 20%, followed by safety at 16% and design quality falls in the last place at only 8% of total response rate.

Table 6.2 : Percentage of complaints by users according to category and size of building

Size of Building/ Complaints Category	**Design Quality (%)**	**Maintenance (%)**	**Building Services (%)**	**User Comfort (%)**	**Safety (%)**
Large	2	6	7	14	4
Medium	1	3	2	6	3
Small	1	3	1	1	5
Combination	4	8	10	14	4
Total	**8**	**20**	**21**	**35**	**16**

One should note that complaints in the design quality category are almost non-existent. That is probably because most people still believe building design and building operation and maintenance are entirely separated. Generally, when building users have complaints, they mainly believe that their problem is caused by inefficiencies in building operation/maintenance rather than by design deficiencies.

6.2.4 Building Management Factors

Question 13 was designed to examine the factors that maintenance firms consider important when maintaining buildings. Similar to the factors used in Question 12, they were asked to rank 22 factors in order of importance whereby these factors were divided into five categories of design quality, maintenance, building services, user comfort and safety. A scale of importance of 1 to 5 is used where 1 represents not important, 2 not very important, 3 important, 4 very important and 5 extremely important. Figure 6.7 presents the distribution of the factors in order of importance by maintenance firms in managing a building .

Analysis in Figure 6.5 shows that maintenance factors (which covers cleaning, repair and replacement and access to cleaning) come in at first place with the average score of 4.25. Whereas, the issue of safety which comprises of fire protection, structural constraints, construction methods and security and building services (clean water system, wastewater system, garbage disposal and telecommunication) take up second place with the average score of 4.14 respectively. Followed closely by design quality factors which include functional layout, choice of material and choice of equipment with the average score of 4.05. Lastly but not least is users' comfort (air circulation, humidity, indoor air, vertical transportation, lighting, heat loss/gain, human traffic and noise protection) with the average score of 3.78. Based from this information, it can be concluded that maintenance firms are aware that maintenance issues are of very important aspect and must be closely linked with design aspects. In fact, the average score gathered for every category is at high points and at the level of importance. Therefore, users' comfort must not be taken into light consideration. As they also play important roles in ensuring the maintainability and operation of a building and its system can always be upkeep.

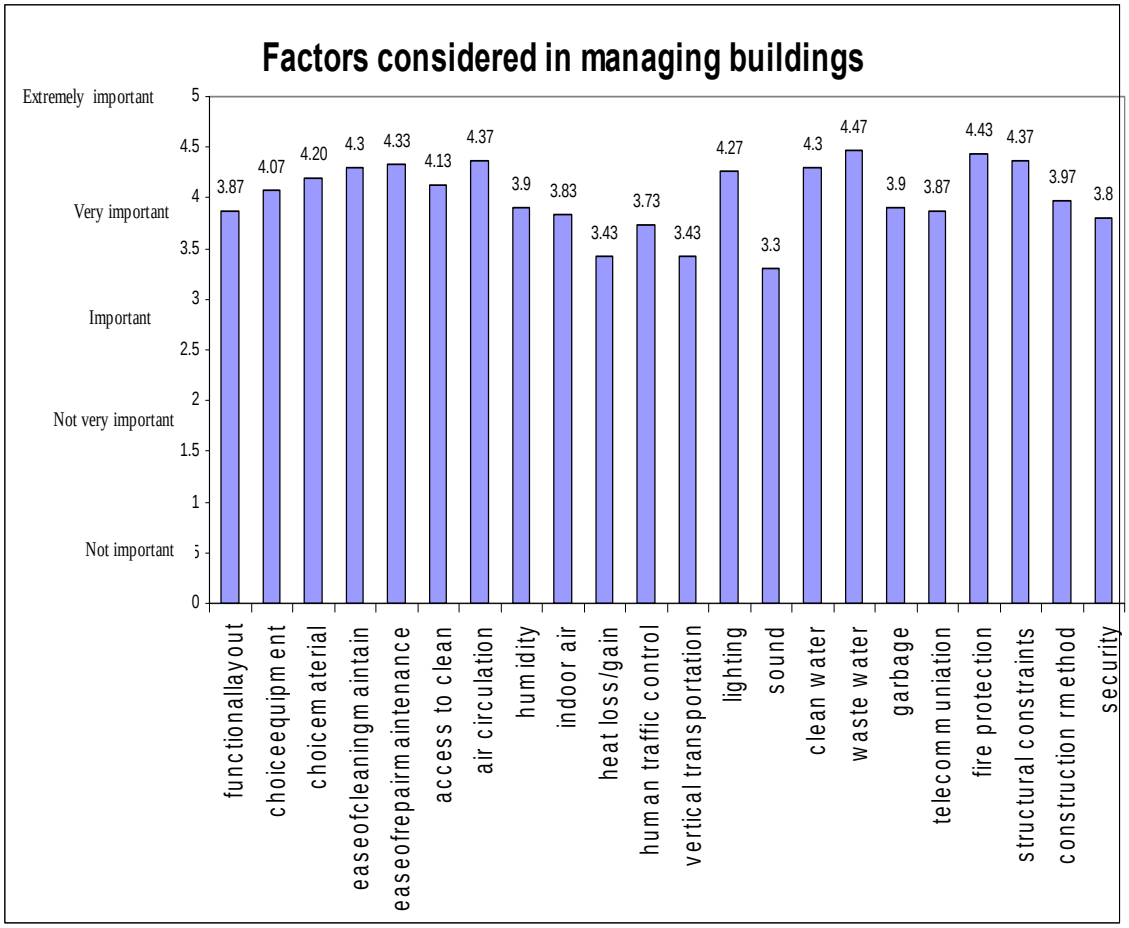


Figure 6.5 Important factors according to maintenance firms in managing buildings

6.2.5 Interactions with Designer Firms

Maintenance and design are frequently treated as if the two activities were not connected. According to Rooley (1992), infrequent communication between property managers and building designers causes design-related maintenance problems. Planning for maintenance in the design process is vital to improve the performance of the constructed facility. Question 14 and 15 were developed to find out the existence of

communication between maintenance firms and designers and if they exist, how far the communication goes. As presented in Figure 6.6, 77% of the respondents have been involved in the design process in one way or another. Only 23% said they have never been involved in the design process of any building that their firm is managing. This finding is similar to a finding in a survey of property managers (Arditi and Narakorawit, 1999) that showed that 85% of the property managers have been involved in the design process of the building they are managing at that time. Analysis of the data in their study shows that while 90% of the respondents who manage buildings owned by their own firms have been involved in the design process formally or informally, only 76% of the respondents who manage buildings own by other organization have done so. Another analysis of the same data by firm age shows that firms with longer experience (94%) pay more attention to the communication with designers than firms with less experience (76%) (Arditi and Narakorawit, 1999).

In response to Question 15, analysis in Figure 6.7 shows that only 27% of the respondents reported that designers would come back only once to visit the building after it was completed, 40% would come back to visit these places periodically while the remaining 30% would never even bother to come back even once to assess the performance of the building they had designed earlier. According to a survey by Arditi and Narakorawit (1999), when communication with the designer is carried out by a design's department located within the property management firm's organization, the designers are likely to return to assess the performance of the building they designed. On the other hand, there is no assessment of building performance when the property management firm was not involved in the design process. It is also interesting to note that whenever a property management firm hires a consultant to represent them in the design process, only 50% of the time is there any assessment of building performance by these designers. The less the property manager's involvement in the design process, the less the designer feels compelled to assess its buildings.

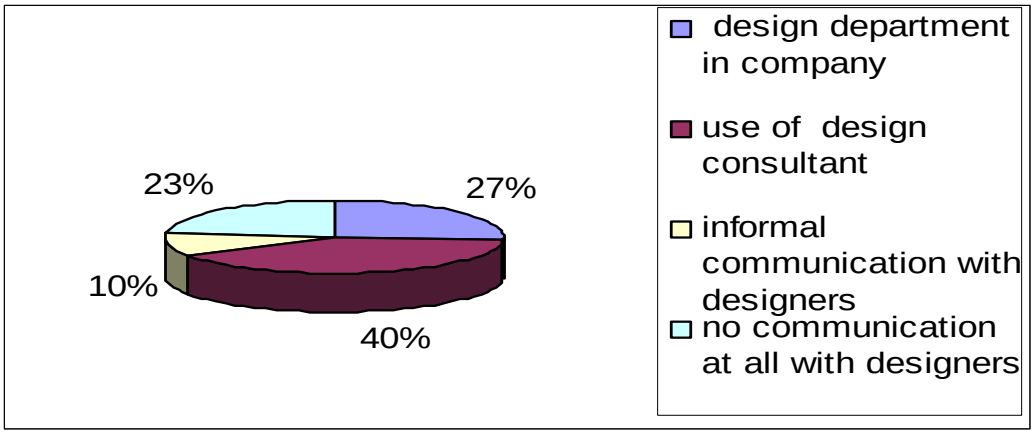


Figure 6.6 Communication between maintenance and designer firms

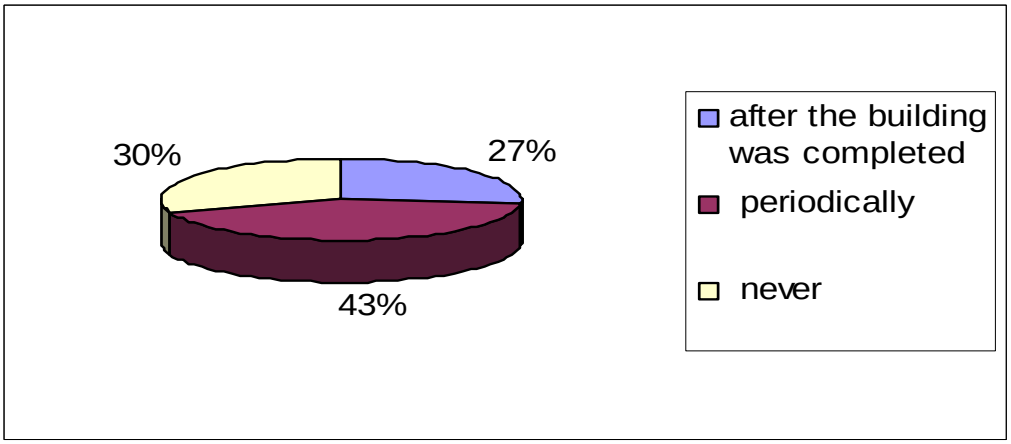


Figure 6.7 Designers' assessment to building performance

6.2.6 Input to Designers

According to the answers to Question 16, maintenance firms would like to advise designers about choice of alternative functional design and building materials (29% respectively), choice of building equipment (22%), choice of building structure (19%) and local climate and environmental considerations (1%) (Refer to Figure 6.8). Because building maintenance works directly to maintain building material, equipment, and structure within acceptable conditions, specifying these components and systems is essential to the efficient operation of the building through its entire life cycle.

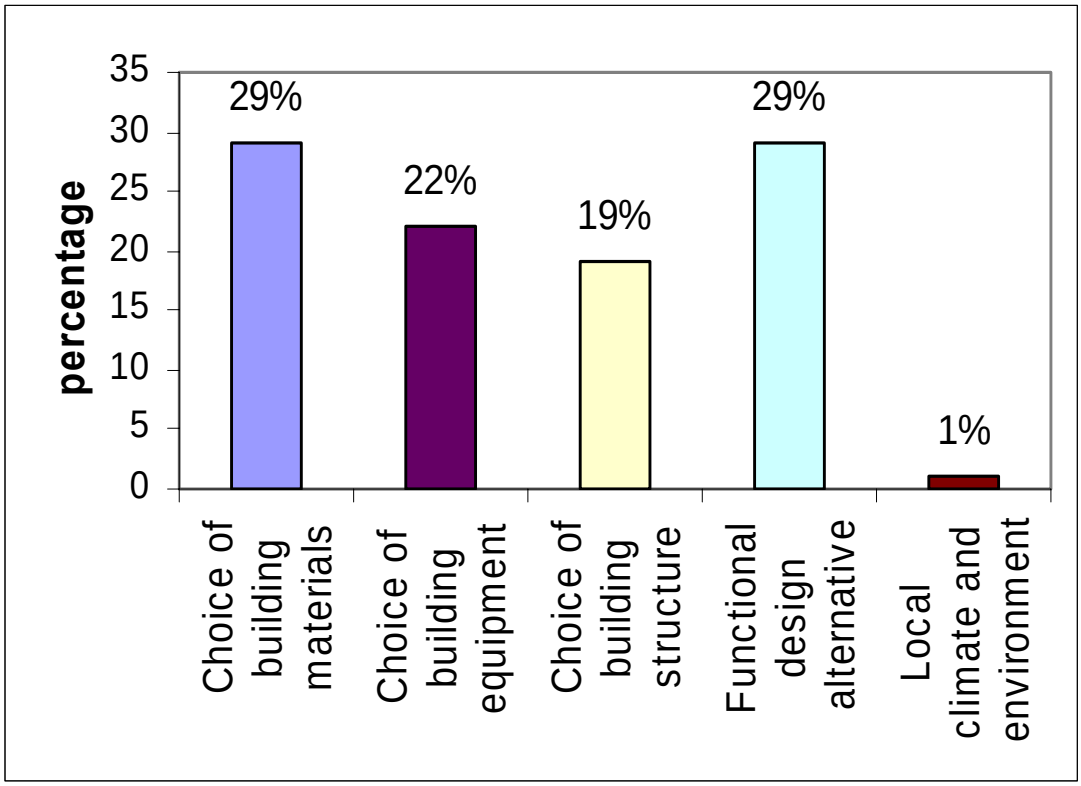


Figure 6.8 Input to designers by maintenance firms

6.2.7 Summary of Findings from Maintenance Firm Questionnaire

Below are the summary of findings gathered from the 30 responding maintenance firms :

(i) Out of 30, 17 (56%) of these firms employ more than 20 employees whereas 37% employ between 11 to 20 employees. Only the remaining 2 firms employ less than 10 staffs. 50% of them have been in business for not more than 20 years whereas the other remaining 50% have been in business for 1 to 10 years.

(ii) 77% of the firms own most of the building they manage, whereas the remaining 23% mostly manage buildings that are owned by other organizations. Maintenance-related services offered by the maintenance firms are mainly on repair and replacement works, inspection, renovation and cleaning

(iii) 41% of the respondents use in-house services for some activities and outsourcing for others, 31% provide all services with in-house capabilities and the remaining 28% rely on complete outsourcing for all services.

(iv) 56% of the firms are managing up to 20 buildings whereas 17% of them manage less than 10 buildings. The least number of buildings which is below 5 is being managed by 27 % of the respondents.

(vi) The top three factors that the maintenance firms use in building selection to decide whether they should manage the maintenance of that building are : firstly, building conditions (19%), secondly, type of building (15%) and thirdly, materials used and building size (13% respectively). Somehow, maintenance firms do not really consider age of building factor when selecting the buildings they want to manage.

(vii) 47% of the respondents reported that the buildings they manage are in average condition, 27% say the building they manage are in good condition whereas 23% of the respondents agreed that their building condition is very good. Only the remaining 3% reported very poor building condition.

(viii) The maintenance-related complaints that the firms have received from building users according to size of the buildings are as follows : user comfort appears to be the number one concern of building users with total response rate of 35% whereas building services is the second most mentioned complaints with total response rate of 21%, maintenance at third place with 20%, followed by safety at 16% and design quality falls in the last place at only 8% of total response rate.

(ix) The maintenance-related problems that maintenance firms experience are as follows : poor construction quality gives the most problem to maintenance firms (24%), closely followed by building design deficiencies (20%), poor performance of the contracted companies (19%) and not enough staff (15%).

(x) The 5 factors that maintenance firms consider important when maintaining buildings in accordance to level of importance are . maintenance factors, safety, building services, design quality and lastly user comfort.

(xi) 77% of the responding maintenance firms have been involved in the design process in one way or another. Only 23% said they have never been involved in the design process of any building that their firm is managing.

(xii) 27% of the respondents reported that designers would come back only once to visit the building after it was completed, 40% would come back to visit these places periodically while the remaining 30% would never even bother to come back even once to assess the performance of the building they had designed earlier.

(xiii) Maintenance firms are well aware that maintenance issues are of very important aspect and must be closely linked with design aspects. Therefore, maintenance firms would like to advise designers about choice of alternative functional design and building materials (29% respectively), choice of building equipment (22%), choice of building structure (19%) and local climate and environmental considerations (1%).

6.3 Designer Firm Questionnaire

Most of the responding firms (42%) employ not more than 10 employees (Question 1), and 66% of the respondents have been in business for not more than 20 years (Question 2). The firms are relatively quite established and registered members due to the fact that the mailing list was obtained from the Association of Consulting Engineers Malaysia (ACEM) and The Institute of Architects Malaysia (PAM) respectively. The firms offer a variety of services including architecture (43%), engineering (40%), project management (9%), consultancy (4%) and interior design (4%) (Question 3).

Answers to Question 4 indicate that 46% of the firms get their work from developers, 30% from direct owners and the remaining 24% from government organizations. The major building types that the firms design are 31% residential, 25% commercial, 21% business, 19% industrial, 3% recreational and 1% educational. Most of the respondents design more than one type of building, except those that specialize in industrial buildings and marine structures (Question 5).

6.3.1 Designers' View in Building Equipment and Material

A major issue during detailed design is the selection of materials, components and equipment and choice is becoming difficult nowadays (Ahmad, 2003). As human venture into advanced technological research and discover new findings which benefits in terms of time, cost, quality, safety and aesthetic values, the pressure to change a building from traditional approach to a highly advanced state immense. This lead to

few consequences. Firstly, the designer need to specify and select the best choice out of an extremely large range of products, all of which might give performance requirement by standard. More over, designers are exposed to lobbying to use one product rather than another, depend on which product or material is highly publicized. Somehow this can lead to another consequences. It is either the designer will choose a new component, equipment or building material which has not been sufficiently proved in practice and is potential to fail standard requirements. Or, the designer might ended by not using at all the equipment or building components, instead he settle down with equipment or building materials that he is familiar with, regardless it is the right choice or not.

Designers, especially those involve in building service facilities such as hospitals, schools, laboratories and police stations must investigate low-maintenance design options. Costs savings over the life of a building can be done if using durable and relatively care-free materials. Usually, low-maintenance materials are more expensive than less durable products but the life cycle of the materials maybe as long as the life cycle of the building, thus, higher up-front costs will eventually paid back and usually exceeded by long-term savings (Ephron, 1989).

Designers were asked in Question 6 to rank the criteria they use when they specify building materials in order of importance. The distribution of this answer is presented in Figure 6.9 on a scale of 0 to 3, where 0 represents not important and 3 most important. Most of the respondents believe that the cost of materials is the most important criterion with an average score of 2.7. The second is maintenance and availability (both scored 2.2 respectively) and the third is aesthetic value (score 1.9). It appears that satisfying the initial cost and maintenance requirements and availability of materials is the major objectives of these firms.

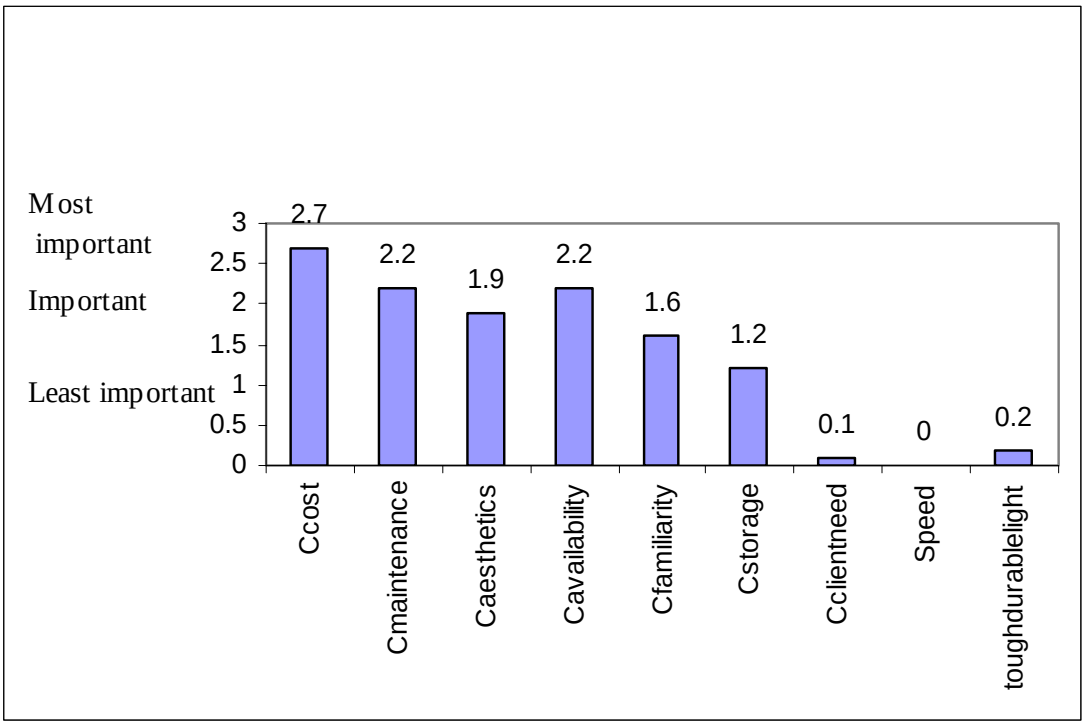


Figure 6.9 Criteria used by designers in specifying materials for buildings

6.3.2 Designers' Existing Maintenance-Related Knowledge

To satisfy the requirements for a building, four guiding principles can be identified (Chanter and Swallow, 1996) :

(i) To produce a building that is appropriate and efficient for the function it houses

(ii) To produce a building that provides the optimum physical and psychological environment for the contents of the building

(iii) To produce a building that strikes an appropriate balance between initial and operation costs

(iv) To produce a building that is consistent with the needs and aspirations of the community at large

Thus, designers are expected to be sensitive not only to matters related to function, user comfort and environment, but also in striking the right balance between initial costs and cost in use (Arditi and Narakorawit, 1999).

Question 7 and 8 were asked to determine how frequently designers are subjected to training in maintenance-related matters and the respondents perception of their personnel' knowledge in this matter. For Question 7, most respondents (41%) indicate that they sometimes receive training on building operation and maintenance or related subjects. 16% of the respondents often attend seminars and trainings on maintenance skills and knowledge, 32% rarely and only the remaining 11% never (refer to Figure 6.10).

When asked in Question 8 to rank the level of maintenance knowledge of architects/engineers in designers' firms, the large majority of the responding designers indicated that it is fair (44%), good (32%), very good (13%) and poor (11%) and none said very poor. The findings in Question 7 and 8 are closely linked together because the level of knowledge is related to the level of training. Analysis in Table 6.3 and Table 6.4 indicates that when the level of knowledge and level of training are analyzed according to the age of the firm, older firms appear to have ranked themselves slightly higher than younger firms.

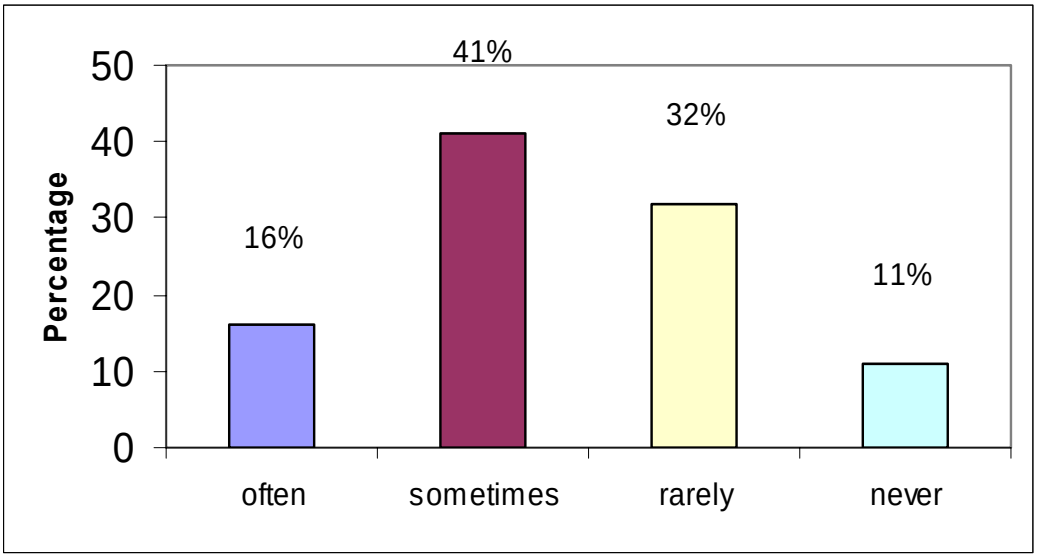


Figure 6.10 In-house training or outside seminars on building operation and maintenance

Table 6.3 : Age of firms and level of training in building operation and maintenance

		Do any members of your company attend in-house training or outside seminars on building operation				Total
		often	Sometimes	rarely	never	
How long has your company been in the business of consultation?	less than a year	0	1	0	1	2
	1-10 years	1	4	4	0	9
	10-20 years	5	10	7	3	25
	more than 20 years	0	1	1	0	2
Total		6	16	12	4	38

Table 6.4 : Age of firms and level of knowledge in building operation and maintenance

		How would you relate the level of knowledge of designers in your company regarding building				Total
		very good	good	fair	poor	
How long has your company been in the business of consultation?	less than a year	0	0	2	0	2
	1-10 years	0	5	3	1	9
	10-20 years	5	7	11	2	25
	more than 20 years	0	0	1	1	2
Total		5	12	17	4	38

6.3.3 Interaction with Maintenance Firms

Right from the very beginning of a project, in which the project is still under preliminary phase, until the project is completed and operated, a number of activities are undertaken by different groups of people, who may have direct and indirect relationship to the primary objectives of the project. The effectiveness with which these activities are carried out will have a major influence on the success or failure of the project. It is vital that all parties have a common basic knowledge and with good communication system that would properly coordinates the activities of the people involved (Arditi and Narakorawit, 1999).

Most people believe that the management of a building begins after the building is built. In reality a building project involves five life-cycle stages of development :

feasibility study, design stage, construction, operation and maintenance. The efficiency, convenience, life span, economic viability, aesthetic value and overall performance of a building can be affected by decisions taken and actions performed at any time in the history of a building project, from its initial conception to its final demolition. The design stage is a critical stage in the life cycle of a building in as much as most critical decisions are made at this stage. The decisions made in the design stage affect all decisions made in subsequent stages and vice versa. That is why the designer's relationship with the other participants in the construction and operation stages is very important. Question 9 till 12 were developed to investigate the level of designers' interaction with future building managers or maintenance consultants and in which phase of the design process this communication takes place.

Question 9 was designed to see if any communication takes place during the design process between the designers and the future building managers of the building. The distribution of the answer is presented in Figure 6.11. 37% of the responding designers answered they sometimes communicate with and receive input from future building managers, 22% answered often, 19% always, 14 % rarely and the remaining 8% answered rarely or never. This finding is almost in line with the finding in a parallel survey of maintenance firms where 77% of the respondents stated that they had some formal and informal communication with building designers during the design phase. However, in the same survey of maintenance firms, the responding maintenance firms also claimed that only 27% of the respondents would come back only once to visit the building after it was completed, 40% would come back to visit these places periodically while the remaining 30% would never even bother to come back even once to assess the performance of the building they had designed earlier.

When the responses to Question 9 are analyzed by the firm's age, it is observed through the detailed distribution of the answers in Table 6.5 that older designers' firms, particularly with the age between 10 to 20 years communicate with building managers

more than the younger firms. This is due to the fact that these older firms have been long aware that, through experience over the years, communication with other parties, particularly with maintenance expertise, is definitely important to broaden their knowledge.

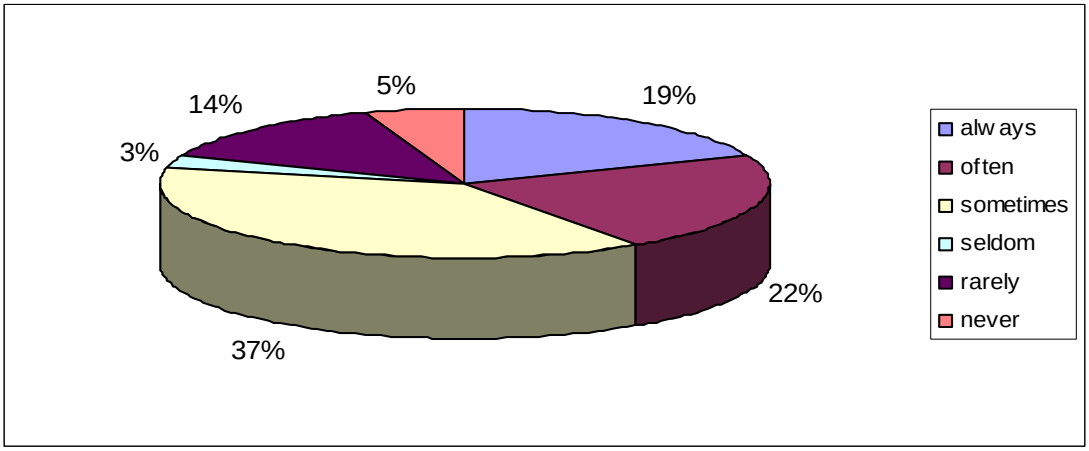


Figure 6.11 Designers get input from future building managers

Table 6.5 : Age of designer firms and communication with maintenance firms

		always	often	sometimes	seldom	rarely	never	Total
How long has your company been in the business of consultation?	less than a year	0	1	1	0	0	0	2
	1-10 years	1	1	3	1	3	0	9
	10-20 years	6	6	8	0	2	2	24
	more than 20 years	0	0	2	0	0	0	2
Total		7	8	14	1	5	2	37

Question 10 determined whether or not the respondents engage building maintenance consultants during the design process. Figure 6.12 shows that most of the respondents (58%) indicated that they did not assign any maintenance consultants in all their projects. Of the remaining 42% who reported using the maintenance expertise in their projects, only 5% consulted the maintenance consultants in ALL their projects. Probably this is due to that these designers' firms have accumulated experiences and well experienced in-house staffs or maintenance expertise. They would probably have frequent in-house training programs and they consider themselves quite knowledgeable in maintenance matters. Therefore, contract outsourcing of maintenance consultants may be unnecessary in some responding firms.

Question 11 was asked to determine in which stage of the design process the input from maintenance expertise is most important. Most of the designer firms (33%) believed that a maintenance consultant would be most valuable when the project is in

the preliminary design stage. The majority, about 65% of the responding designers agreed that maintenance consultants would be most effective when the projects are

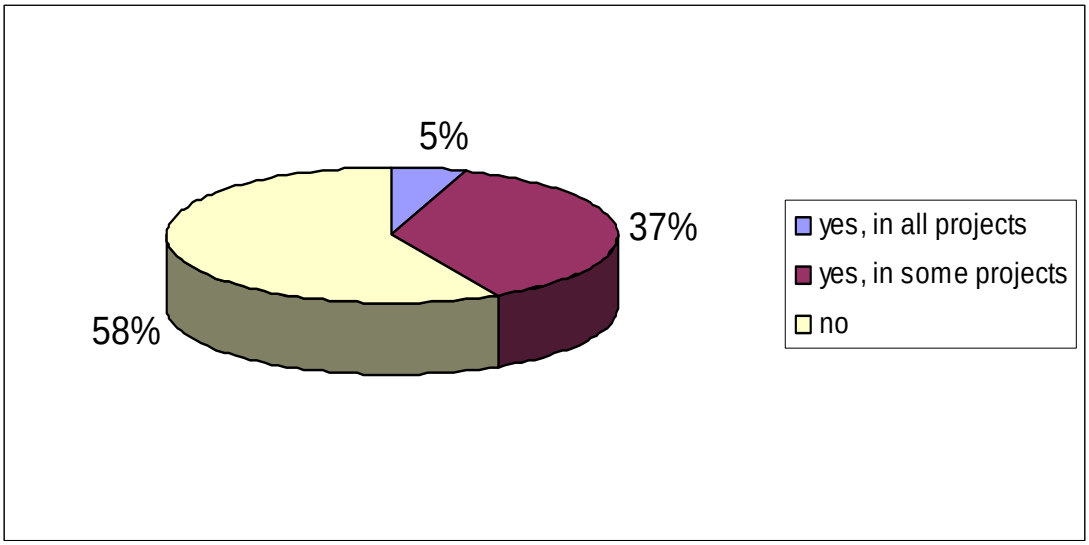


Figure 6.12 Engagement of maintenance consultants during design stage

within the front part of the design process that is preliminary design (33%), schematic design (15%) and conceptual design (17%). Whereas the remaining 35% (final design [10%]) and detail design [25%]) opted for the end part of the design process. This is most likely because they realize the importance of advance planning in maintenance.

It is generally believed that poor detailed design practices are the source of a large proportion of performance problems during the life of a building especially when potential maintenance-related problems are not reviewed in detail starting from preliminary design stage itself.

6.3.4 Complaints On Maintenance-Related Problems

It is reasonable to assume that building projects are normally completed with different degrees of success. Question 13 and 14 were asked to examine how and what clients report back to their design firms on design or related subjects. Results show that 63% of the responding designers received complaints from the building owners whereas the remaining 37% do not receive any complaint at all. According to analysis in Table 6.6, the number of complaints is not very different between the older designer firms and the younger designer firms. Most probably technology changes so fast that there is not much time to learn and avoid making the same mistakes again. Or, probably, either firms do not learn from their mistakes through good feedbacks and records.

Table 6.6 : Age of business and complaints received from building owners

		Is your company receiving complaints from clients regarding the maintenance of the buildings designed			Total
		yes	yes, but not all the buildings designed	no	
How long has your company been in the business of consultation?	less than a year	0	1	1	2
	1-10 years	0	7	2	9
	10-20 years	2	12	11	25
	more than 20 years	0	2	0	2
Total		2	22	14	38

Figure 6.13 presents the sources of the major-maintenance related complaints that designers received from clients (Question 14).

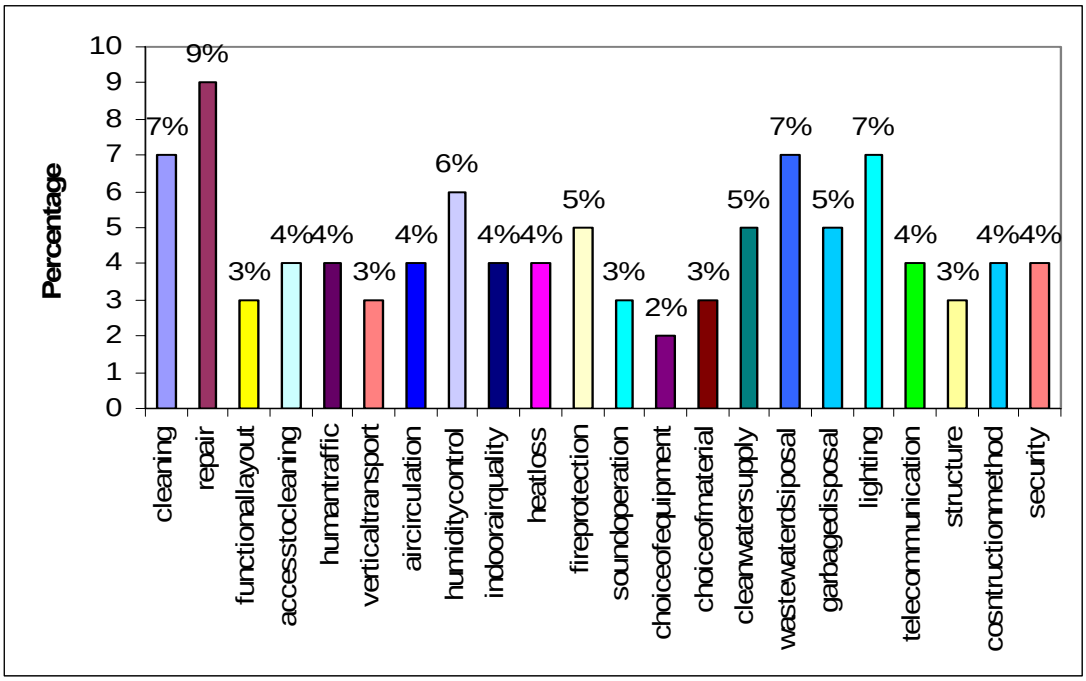


Figure 6.13 Complaints received from building users

The complaints that were listed in Question 15 are categorized in five groups :

(i) Design quality – includes functional layout, choice of equipment and choice of materials

(ii) Maintenance – includes cleaning, repair/replacement and access to cleaning areas

(iii) User comfort – includes air circulation, indoor air quality, humidity control, heat loss/heat gain, lighting, human traffic, vertical transportation and noise protection.

(iv) Building services – includes clean water supply, wastewater disposal, garbage disposal and telecommunication

(v) Safety – fire protection, structural constraints, construction methods and security

According to analysis in Figure 6.13, complaints of repair and/or replacement works (under maintenance category) come in at first place with 9% in the list of complaints by building users. Following closely are cleaning works (maintenance), waste water disposal (building services) and telecommunication (building services) at 7% respectively, 6% on humidity control (user comfort) and 5% on fire protection (safety), clean water supply (building services) and garbage disposal (building services) respectively. Whereas factors like access to cleaning areas, human traffic, air circulation, indoor air, air quality, heat loss, telecommunication, construction method and security were reported by 4% of the respondents. Functional layout, vertical transportation, choice of material, sound protection and structural complaints were reported by only 3% of the respondents and finally, only 2% answered choice of equipment which is under the design quality category.

Analysis show that user comfort appears to be the number one concern of building users with total response rate of 35% whereas building services is the second most mentioned complaints with total response rate of 21%, maintenance at third place with 20%, followed by safety at 16% and design quality falls in the last place at only 8% of total response rate. On the other hand, designers do not consider these factors at the top of their priority list when they make design decisions (refer to Figure 6.14).

Question 15 was designed to examine the factors that designer firms consider important maintenance factors when designing buildings. Similar to the factors used in Question 14, they were asked to rank 22 factors in order of importance whereby these factors were divided into five categories i.e. design quality, maintenance, building services, user comfort and safety. A scale of importance of 1 to 5 is used where 1 represents not important, 2 not very important, 3 important, 4 very important and 5 extremely important. Figure 6.14 presents the distribution of the factors in order of importance by designer firms in designing a building .

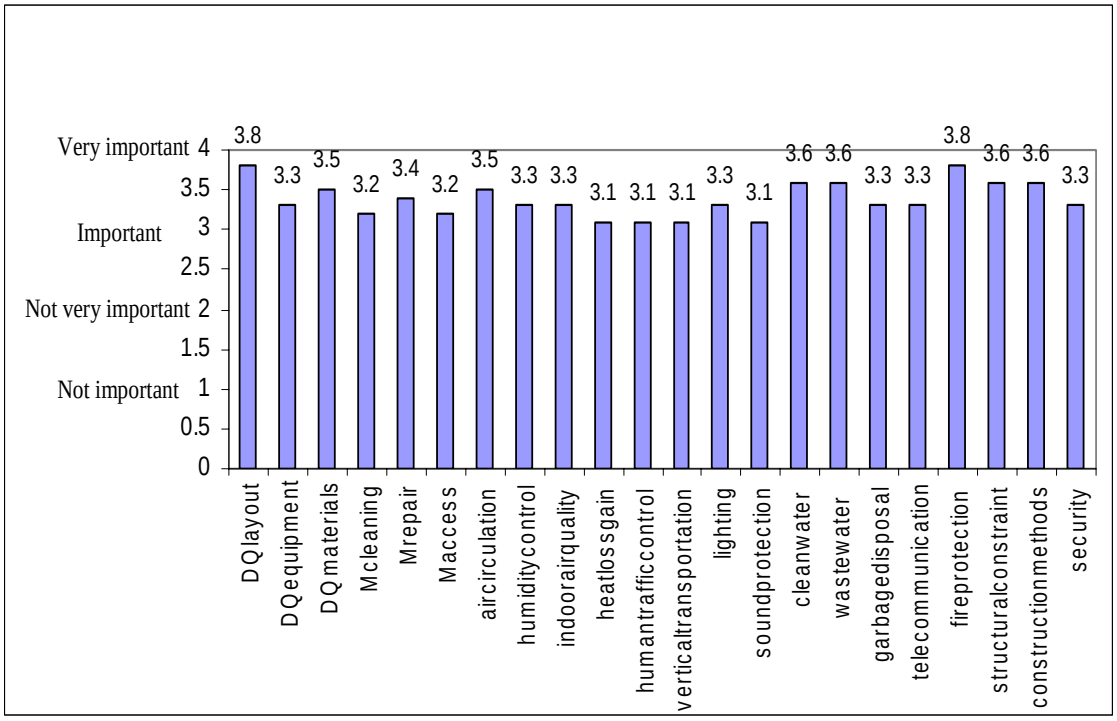


Figure 6.14 Important maintenance factors according to designer firms in managing buildings

Analysis in Figure 6.14 shows that designer prioritize the safety factor with the average score of 3.58, followed closely by design quality factors (3.53), building services (3.45), maintenance factors (3.27) and lastly user comfort with the score of average 3.23. Out of the list of 22 factors, the factors in maintenance category rank 9th, 17th and 18th in the order of importance according to designer firms' perspective. In the same survey carried out on maintenance firms, similar questions was asked with exactly the same choice of factors and comparison of findings between designer firms and maintenance firms were made (refer to Table 6.7).

It appears that building designers do not really consider maintenance factors when they design and manage buildings and this goes along with earlier findings which

reported that (58%) of responding designer firms indicated that they did not assign any maintenance consultants in all their projects. Probably, this is because of building owners' emphasis on initial costs of projects and ignore the cost of upkeep, inspection, repair and replacement.

Table 6.7 : Comparison of five most important maintenance factors in designing building

Designer Firms	1. Security 2. Design layout . 3. Building services 4. Maintenance 5. User comfort
Maintenance Firms	1. Maintenance 2. Building services 3. Safety 4. Design layout 5. User comfort

6.3.5 Summary of Findings from Designer Firm Questionnaire

Below are the summary of findings gathered from the 38 responding designer firms :

(i) Most of the responding firms (42%) employ not more than 10 employees and 66% of the respondents have been in business for not more than 20 years. The firms are relatively quite established and registered members of Association of Consulting Engineers Malaysia (ACEM) and The Institute of Architects Malaysia (PAM) organization respectively. The firms offer a variety of services including architecture (43%), engineering (40%), project management (9%), consultancy (4%) and interior design (4%).

(ii) In specifying building materials, most of the responding designer firms believe that the cost of materials is the most important criterion followed by maintenance and availability (both scored the same respectively) and the last is aesthetic value.

(iii) Most respondents (41%) indicate that they sometimes receive training on building operation and maintenance or related subjects. 16% of the respondents often attend seminars and trainings on maintenance skills and knowledge, 32% rarely and only the remaining 11% never attended any.

(iv) The level of maintenance knowledge of architects/engineers in designers' firms, majority of the responding designers indicated that it is fair (44%), good (32%), very good (13%) and poor (11%) and none said very poor.

(v) 37% of the responding designer firms answered they sometimes communicate with and receive input from future building managers, 22% answered often, 19% always, 14 % rarely and the remaining 8% answered rarely or never. It is observed that older designers' firms, particularly with the age between 10 to 20 years communicate with building managers more than the younger firms.

(vi) 65% of the responding designer firms agreed that maintenance consultants would be most effective when the projects are within the front part of the design process that is preliminary design (33%), schematic design (15%) and conceptual design (17%). Whereas the remaining 35% (final design [10%]) and detail design [25%]) opted for the end part of the design process.

(vii) The maintenance-related complaints that the designer firms have received from building users are as follows : user comfort appears to be the number one concern of building users with total response rate of 35%, secondly building services (21%), thirdly maintenance (20%), fourthly safety (16%) and lastly design quality which falls in the last place at only 8% of total response rate.

(viii) The factors that designer firms consider important when designing building, they are : the safety factor with the average score of 3.58, followed closely by design quality factors (3.53), building services (3.45), maintenance factors (3.27) and lastly user comfort with the score of average 3.23.

6.4 Critical Factors When Designing A Building

The primary purpose of this research is to determine the critical factors need to be looked into seriously by designer firms before and during designing of buildings. This is to ensure that the concept of ease of maintenance during design stage is well understood and implemented. Using a combination of recent literature, a questionnaire survey and interviews and validation by the industry professionals, the researcher came up with eight critical factors :

1. Develop design for ease of maintenance concept at the management level. Management should be made aware with the objective, concept and method of design for ease of maintenance and its impact and benefits on a project in the context of long term cost, schedule and safety.

2. Form a policy which include design for ease of maintenance objective, commitment from management, funding from project owners and close linkage to construction implementation.

3. Identify current maintenance practices and opportunities for future improvement. Benchmarking against industry standard will provide reference points.

4. Develop procedures which provide framework and assure consistent implementation of design for ease of maintenance activities. The procedure must include frequency of meetings, design checklists, trainings and human resources to carry out the activities.

5. Form design for ease of maintenance implementation committee to develop the design process and implement it on pilot projects, assess the process and results and put in lesson-learned database for future references and recommendations for more successful results for future projects.

6. Define maintenance strategy based on current maintenance practices be it corrective, planned, predictive or proactive maintenance. Take into consideration types of equipment used , system, assess in-house experiences and capabilities, define roles and responsibilities and apply appropriate design.

7. Conduct design for ease of maintenance meetings and discussions according to schedule, to address specific issues in more detail and report the outcome back to the management and later to the main project team.

8. Formal checklists and reviews ensure that the project design team addresses the design for ease of maintenance objectives. Checklists allow design and maintenance inputs from different groups of expertise be documented, tracked and fed into the design and will serve as a guide during formal design reviews.

CHAPTER 7

CONCLUSION AND RECCOMENDATION

7.1 Conclusion

A research was conducted of 30 maintenance firms and 38 designer firms in Shah Alam and Kuala Lumpur districts to identify building defects due to poor maintenance considerations during design and to identify maintenance and design factors for designers. The conclusions gathered from the study are as follows :

1. **To identify building defects that are related to poor maintenance consideration during design stage**.

   Three main building defects related to poor maintenance consideration during design stage that the maintenance firms currently face are

   (i) building design deficiencies which include the functional layout, choice of building materials and choice of equipment

(ii) poor construction quality which involves the workmanship, supervision, construction method and materials used (construction method and type of material used are based on decision made during design stage) and

(iii) poor performance of building which is directly related to functional layout, choice of building material and choice of building equipment.

2. **To identify critical maintenance factors in civil and architectural designs**

The are 8 critical factors need to be considered by designers when designing a building. These factors are :

1. Develop design for ease of maintenance concept at the management level. Management should be made aware with the objective, concept and method of design for ease of maintenance and its impact and benefits on a project in the context of long term cost, schedule and safety.

2. Form a policy which include design for ease of maintenance objective, commitment from management, funding from project owners and close linkage to construction implementation.

3. Identify current maintenance practices and opportunities for future improvement. Benchmarking against industry standard will provide reference points.

4. Develop procedures which provide framework and assure consistent implementation of design for ease of maintenance activities. The procedure must include frequency of meetings, design checklists, trainings and human resources to carry out the activities.

5. Form design for ease of maintenance implementation committee to develop the design process and implement it on pilot projects, assess the process and results

and put in lesson-learned database for future references and recommendations for more successful results for future projects.

6. Define maintenance strategy based on current maintenance practices be it corrective, planned, predictive or proactive maintenance. Take into consideration types of equipment used , system, assess in-house experiences and capabilities, define roles and responsibilities and apply appropriate design.

7. Conduct design for ease of maintenance meetings and discussions according to schedule, to address specific issues in more detail and report the outcome back to the management and later to the main project team.

8. Formal checklists and reviews ensure that the project design team addresses the design for ease of maintenance objectives. Checklists allow design and maintenance inputs from different groups of expertise be documented, tracked and fed into the design and will serve as a guide during formal design reviews.

7.2 Recommendations

For future research, it is recommended that a thorough survey be conducted on different types of building such as survey on office buildings, residential, industrial, sports etc respectively. Due to the fact that different type of building portrays different characteristics in terms of design and maintenance system employed. It is also recommended that the outlined critical factors for building designer firms consideration be carried out on pilot projects in order to determine its effectiveness on the local construction industry and local practice to enable further improvement be made for the benefits of other future projects.

REFERENCES

Ahmad Ramly (2003). Link between Design and Maintenance. *Seminar on Building Management and Maintenance.* May 12-13. Kuala Lumpur.

Alner, G.R. and Fellows,R.F. (1999). Maintenance of Local Authority School Building in UK: A Case Study. *Proceedings of the International Symposium on Property Maintenance Management and Modernisation.* Singapore.

Arditi, D. and Nawakorawit, M. (1999). Designing Buildings for Maintenance : Designers' Perspective. *Journal of Architectural Engineering.* United States of America.

Assaf, S., Al-Hammad, A.M and Al-Shihah, M. (1996). Effects of Faulty Design and Construction on Building Maintenance. *Journal of Performance of Constructed Facilities*. 23(3):175-181.

Chew, M.Y.L., Wong, C.W. and Kang, L.H. (1999). Building Façade - A Guide to Common Defects in Tropical Climates. *World Scientific.* Singapore.

Chew, M.Y.L., Tan, S.S. and Kang, K.H. (2004). Building Maintainability - Review of State of the Art. *Journal of Architectural Engineering*. United States of America.

Clift, M. and Butler, R. (1995). *The Performance and Cost in use of Buildings: A New Approach*. Technical Report. Building Research Establishment. United Kingdom.

Corder, A.S. (1976). *Maintenance Management Technique*. New York: McGraw Hill Inc. Publisher.

William, B. (1993). What a Performance!. *Property Management.* 11(3): 190-101.

Moua, B. and Russell, J. (2001). Comparison of Two Maintainability Programmes. *Journal of Construction Engineering Management.* 239-244.

David, W.W. and Arthur, B. (1989). Management to Maintain Quality in Buildings. *Proceedings of Implementation of Quality in Construction*. Copenhagen.

Dunston, P. and Williamson, Craig. (1999). Incorporating Maintainability in Constructability Review Process. *Journal of Management in Engineering.* United Kingdom.

El-Haram, M. and Knezevic, J. (1995). Predictor based Maintenance Methodology. *Proceedings of the 5th International Logistic Symposium*. United Kingdom: 187-194.

K.C. Lam. (1999). *Planning and Execution of Business - Centre Maintenance For Perfect Building in Year 2000*. Building Services Engineering Department: The Hong Kong Polytechnic Univ. in Southeast Asia Facility Management.

Kelly, A. and Harris, M.J. (1978). *Management of Industrial Maintenance.* UK.

Kelly, A. (1989). Maintenance and its Management. *Conference Communication.*UK.

Miles, Derek and Syagga, Paul. (1987). *Building Maintenance-A Management Manual*. 2nd Edition. United Kingdom: Intermediate Technology Publishing Limited.

Patton, J.D. (2000). Maintainability and Maintenance Management. *Journal of Quality in Maintenance Engineering.* 6(3): 138-164.

Priel, V.Z. (1974). *Systematic Maintenance Organization.* London: Macdonald & Evans Publishers.

Raymond, C.M. and Joan, C.F. (1991). *Preventive Maintenance of Buildings.* London: Chapman and Hall Publishers.

Seeley, H. (1976). *Building Maintenance.* London: Macmillan Press Limited.

Stephen, J. H. (2000). Building Services Maintenance - The Forgotten Discipline. *Journal of Architectural Engineering.* 5(9): 118-136.

APPENDIX A

MAINTENANCE FIRM QUESTIONNAIRE

PLEASE TICK (√)) YOUR ANSWER AND FILL IN THE BLANKS ACCORDINGLY

PART A: GENERAL INFORMATION OF YOUR ORGANIZATION

1. Approximately how many full time employees work in your company?

☐	1-10	☐	More than 20
☐	11-20		

2. How long has your company been in the business of managing buildings?

☐	Less than a year	☐	10-20 years
☐	1-10 years		

3. What is the status of the building your company is maintaining?

☐	Most are owned by our company
☐	Most are owned by others
☐	Some are owned by our company, some by others

4. What maintenance services does your company offer? (Check all that apply)

☐	Cleaning	☐	Renovation
☐	Repair		
☐	Inspection		

☐ Other, please specify_____

5. How does your company provide these services?

☐	Mostly in-house service department
☐	Mostly contract outsourcing
☐	Selective outsourcing

6. Approximately how many buildings is your company maintaining?

☐	Fewer than 5 buildings		
☐	6-10 buildings		
☐	11-20 buildings		

7. What guidelines does your company use to decide whether it should manage the maintenance of a building? (Check all that apply)

☐	Age of building	☐	Building design
☐	Building size	☐	Location
☐	Type of building	☐	Owner's reputation
☐	Building condition	☐	Number of building being currently managed
☐	Materials used in the building		
☐	Other, please specify_____		

8. On the average, how old are the buildings your company is managing?

☐	Relatively new buildings (Less than 10 years old)
☐	11years old buildings and above
☐	Combination of the above

9. On the average, how would you categorize the overall condition of the buildings your company is managing?

☐	Very good	☐	Poor
☐	Good	☐	Very poor
☐	Average		

10. What is the average size of the buildings your company is managing?

☐	Large buildings
☐	Medium size buildings
☐	Small buildings
☐	Combination of the above

PART B: MAINTENANCE

11. In your experience, what are the problems your company faces in building maintenance? (Check all that apply)

☐	Not enough staff	☐	building design inefficiencies
☐	Too many calls for service	☐	Service administration inefficiencies
☐	Not enough money	☐	Poor construction quality

☐ Poor performance of the contracted company

___Other, please specify_____

12. What are the maintenance-related complaints that your company receives from clients? (Check that all apply)

	Cleaning		Indoor air quality		Wastewater disposal
	Repair/ replacement		Heat loss/heat gain		Garbage disposal
	Functional layout		Fire protection		Lighting
	Access to cleaning area		Sound operation		Telecommunication
	Human traffic		Choice of equipment		Structure constraints
	Vertical transportation		Choice of materials		Construction methods
	Air circulation		Clean water supply		Security
	Humidity control				

13. In your experience, how important are following factors in building maintenance?

Factor	Extremely Important	Very Important	Somewhat Important	Not very Important	Not important
Category					
DESIGN QUALITY					
a. Functional layout					
b. Choice of equipment					
c. Choice of materials					
Category					
MAINTENANCE					
a. Ease of cleaning					
b. Ease of repair/replacement					
c. Access to cleaning area					
Category					
BUILDING USER COMFORT					
a. Air circulation					
b. Humidity control					
c. Indoor air quality					
d. Heat loss/heat gain					
e. Human traffic					
f. Vertical transportation					
g. Lighting					
h. Sound protection					
Category					
BUILDING SERVICES					
a. Clean water supply					
b. Wastewater disposal					
c. Garbage disposal					
d. Telecommunication					
Category					
SAFETY					
a. Fire protection					
b. Structural constraints					
c. Construction methods					
d. Security					
Other, please specify					

14. Have you or members of your organization been involved in the design process of any of the buildings
that your company is managing?

☐	Yes, we have a design department in our company
☐	Yes, we use a design consultant
☐	Yes, informally
☐	No, never

15. Do the designers of the buildings come back to access the performance of the buildings your firm is managing?

☐	Yes, once after the building was completed
☐	Yes, periodically
☐	No, never

16. What input would you wish to give to the designers to avoid the problems you are currently experiencing in building maintenance? (Check that all apply)

☐	Choice of building materials	☐	Choice of building structure
☐	Choice of building equipment	☐	Functional design alternative

☐ Other, please specify_____

_____

17. Are you interested in receiving a summary of the findings of this study?

☐	Yes
☐	No

APPENDIX B

DESIGNER FIRM QUESTIONNAIRE

PLEASE TICK YOUR ANSWER (√) AND FILL IN THE BLANKS ACCORDINGLY

PART A: GENERAL INFORMATION OF YOUR ORGANIZATION

1. Approximately how many full time employees work in your company?

☐	1-10	☐	More than 20
☐	11-20		

2. How long has your company been in the business of consultation?

☐	Less than a year	☐	10-20 years
☐	1-10 years		

3. What kind of service does your company provide?

☐	Architectural design	☐	Engineering design

☐ Other, please specify_____

4. What is the source of most of your company's work?

☐	Developer	☐	Government organization
☐	Direct owner		

☐ Other, please specify_____

5. What kinds of buildings does your company design? (Check all that apply)

☐	Residential	☐	Industrial
☐	Business	☐	Commercial

☐ Other, please specify_____

6. Rank (1 to 3) the criteria you use when you choose materials for a building?
(3 = Most important, 2 = Less important, 1 = Least important)

___	Cost	___	Availability
___	Maintenance	___	Familiarity with the material
___	Aesthetics	___	Storage

___ Other, please specify_____

7. Do any members of your company attend in-house training or outside seminars on building operation and maintenance or a related subject?

☐	Often
☐	Sometimes
☐	Rarely
☐	Never

8. How would you relate the level of knowledge of designers in your company regarding building maintenance?

☐	Very good	☐	Poor
☐	Good	☐	Very poor
☐	Fair		

9. Do designers in your company get input from the future manager of the building they design?

☐	Always	☐	Seldom
☐	Often	☐	Rarely
☐	Sometimes	☐	Never

10. Does your company engage with building maintenance consultants during the design process?

☐	Yes, in all projects
☐	Yes, in some projects
☐	No

11. In which state of the design process do you think input from building maintenance consultants is most important?

☐	Preliminary design	☐	Final design
☐	Schematic design	☐	Detail design
☐	Conceptual design		

12. How often do members of your company have formal meetings with the tenants/clients after construction completed?

☐	Once a year	☐	Four times a year
☐	Twice a year	☐	Every month
☐	Three times a year		

☐ Other, please specify_____

PART B: DESIGN AND MAINTENANCE

13. Is your company receiving complaints from clients regarding the maintenance of the buildings designed by your company? If yes, please answer Question 14. if no, please proceed to Question 18.

☐	Yes
☐	Yes, but not all the buildings designed
☐	No

14. What are the maintenance-related complaints that your company receives from clients? (Check that all apply)

	Cleaning		Indoor air quality		Wastewater disposal
	Repair/ replacement		Heat loss/heat gain		Garbage disposal
	Functional layout		Fire protection		Lighting
	Access to cleaning area		Sound operation		Telecommunication
	Human traffic		Choice of equipment		Structure constraints
	Vertical transportation		Choice of materials		Construction methods
	Air circulation		Clean water supply		Security
	Humidity control				

15. In your experience, how important are the following factors in designing a building?

Factor	Extremely Important	Very Important	Somewhat Important	Not very Important	Not important
Category					
DESIGN QUALITY					
a. Functional layout					
b. Choice of equipment					
c. Choice of materials					
Category					
MAINTENANCE					
a. Ease of cleaning					
b. Ease of repair/replacement					
c. Access to cleaning area					
Category					
BUILDING USER COMFORT					
a. Air circulation					
b. Humidity control					
c. Indoor air quality					
d. Heat loss/heat gain					
e. Human traffic					
f. Vertical transportation					
g. Lighting					
h. Sound protection					
Category					
BUILDING SERVICES					
a. Clean water supply					
b. Wastewater disposal					
c. Garbage disposal					
d. Telecommunication					
Category					
SAFETY					
a. Fire protection					
b. Structural constraints					
c. Construction methods					
d. Security					
Other, please specify					

16. In your opinion, which three building components are most difficult to **clean**? **(Check only three)**

__Interior surface __Exterior surface __Mechanical system	__Electrical system __Telecommunication system __Clean water system	__Wastewater system __Structural system __Roof
__Other, please specify_____		

17. In your opinion, which three building components are the most difficult to **inspect**? **(Check only three)**

__Interior surface __Exterior surface __Mechanical system	__Electrical system __Telecommunication system __Clean water system	__Wastewater system __Structural system __Roof
__ Other, please specify_____		

18. In your opinion, which three building components are the most difficult to **repair and replace**? **(Check only three)**

__Interior surface __Exterior surface __Mechanical system	__Electrical system __Telecommunication system __Clean water system	__Wastewater system __Structural system __Roof
__Other, please specify_____		

19. Are you interested in receiving a summary of the findings of this study?

☐	Yes
☐	No